SOUTH FORK RIVANNA RESERVOIR AND WATERSHED: REFLECTING ON 36 YEARS, ANTICIPATING 50 YEARS

REPORT

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Prepared for
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County of Albemarle, VA
Albemarle County Service Authority
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Finally, this report builds on several previous valuable reports (some summarized in Appendix II). I recognize these previous efforts and hope that this report will be a worthy contribution to the ongoing discussion of managing water resources in Albemarle County and the City of Charlottesville.

Stephen P. Bowler
Spring 2003

EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this report is to review the 36 year history of the South Fork Rivanna Reservoir (SFRR) and the 23 year history of active watershed management with an eye toward updating watershed management planning to protect water resources. The last watershed management plan for SFRR was developed in 1979. The community is currently engaged in a *Water Supply Project* with a planning horizon of 50 years. All indications are that SFRR will remain the dominant water source for years to come.

It is time to revisit the 1979 plan in order to adapt to changes and develop new strategies to address the unsolved challenges. The reservoir water quality issues are both different from and similar to those faced 23 years ago. Water quality, the watershed landscape, drinking water regulations, and watershed management techniques have all changed. At the same time, sedimentation rates and development rates have remained stubbornly persistent. The community must learn from and build upon the watershed management efforts of the past to avoid putting the SFRR at increased risk of water quality and quantity problems just as we are putting more emphasis on it as a water supply.

SOUTH FORK RIVANNA CHARACTER AND ECOLOGY

The SFRR is a long, narrow water body with a very large watershed giving it the characteristics of both a river and a lake. The result is relatively consistent water supply, but also large pollutant loads and management challenges. Many of the problems with SFRR relate to the same thing that makes it a useful water supply- its ability to hold back water. The increased water residence time relative to the natural river provides storage for drinking water but also allows pollutants to be trapped.

The watershed falls almost entirely in the County of Albemarle putting prime responsibility for its care in local hands. As of the early 1990s, the watershed was 73% forested (the best land use for water quality and quantity protection). However, much of the watershed alteration that threatens water quality, as reflected by increased acreage of roads, driveways, rooftops and lawns, appears to have occurred along the tributaries closest to the reservoir.

A major issue is sedimentation, which causes an average annual rate of lost drinking water storage capacity of 1.1% (0.92% of total reservoir volume). Sedimentation is a natural process accelerated by human activities. Over-enrichment (eutrophication), another human acceleration of a natural process, is an additional problem in the reservoir. Eutrophication is not extreme (as it probably was in the 1970s) but is important to keep at a minimum. Pathogens and potentially hazardous chemicals do not cause problems for water treatment but always require vigilance. Weather conditions at both extremes (dry and wet) exacerbate reservoir problems. The watershed as an ecosystem has characteristics that provide natural water quality protection or resilience. These features need to be protected and enhanced wherever possible. They include the forests (particularly the streamside forests), wetlands, and the stream network.

WATERSHED MANAGEMENT HISTORY AND ISSUES

The local community has done a great deal to protect the SFRR over the years making it a regional leader in watershed protection. Highlights include multiple studies of the reservoir, the 1979 management plan, creation of a full-time staff position, a major down-zoning, and development of ordinances to deal with stormwater, erosion control, and stream buffer protection. There have also been changes at the state and federal level that have benefited the SFRR.

RESERVOIR AND WATERSHED CHANGES OVER TIME

Land Use

The stated justification of the 1980 rezoning effort was that it would help to achieve the complementary goals of rural preservation and water quality protection. In spite of the rezoning and policy changes, there has been a pattern of conversion of rural land to suburban land use. The trend is toward relatively small parcels and a decline in farm acreage. Much of the SFRR Watershed has a growth rate higher than average for designated rural areas, but somewhat lower than designated growth areas.

Sedimentation

Sediment loads have varied greatly over the years, probably as a result of the occurrence of large storm events. However, the amount of sediment generated relative to the storm intensity did not change in a measurable way in the 1980s and 1990s. This finding suggests that the human influence did not increase or decrease the sedimentation process.

Sediment reduction goals and strategies will need to be refined by developing a greater understanding of various sediment sources and their relative importance. Enhancement of stream buffer vegetation is a strategy at hand immediately. Traditional sediment control strategies such as erosion and sediment control at construction sites and agricultural management practices will continue to be important.

Enrichment and Related Issues

Since monitoring began in the early 1980s, phosphorus concentrations in the reservoir are clearly down (about 40%). Nitrogen concentrations appear to be down as well. The main source of this improvement was probably the Crozet sewage interceptor installed in 1988. Additional likely factors were a gradual decline in row crop agriculture, a state-wide ban on phosphate detergents, installation of agricultural best management practices (BMPs), and construction of the Lickinghole Creek Stormwater Basin. The nutrient reductions in the 1980s and 1990s may have built upon other, unmeasured reservoir improvements in the middle and late 1970s that resulted from the federal Clean Water Act and reservoir maturation. Since the late 1980s, operation of the hydropower plant or some other factor may have led to increases in the algae community in spite of the phosphorus reductions. (See pages 63-66 of the full report for details.) If algae have increased, the issue has not translated into significant water treatment problems. Had the phosphorus reductions not occurred, it is possible that the algae problems that took place in the 1960s, 70s, and early 80s would have reappeared.

Toxins, Metals, and Pathogens

The initial study of the SFRR reported in 1977 that there were no significant problems with metals or other potential toxins in the reservoir. There is no reason to believe there has been any change in this status. The finished water is comprehensively analyzed annually and is meeting all standards. Despite little evidence of problems, this issue should always be monitored. Similarly, the finished water is free of problems with pathogens. However, efforts should continue to minimize pathogens in the raw water.

Other Issues

Several specific issues could be addressed in future watershed management efforts. Among these are the potential impact of septic systems on drinking water, risks associated with the US 29 western bypass, livestock access to the reservoir and its tributaries, and minimizing chlorination by-products (that are related to eutrophication). Strategies might be considered to reduce the impacts of both the Sugar Hollow Dam and the South Fork Rivanna Dam on downstream ecosystems without threatening water supply. County stormwater policies regarding the regional Lickinghole Basin may need to be revisited. The land application of biosolids is another up-and-coming issue in Virginia.

Overall

The SFRR Watershed is a microcosm of water quality in the United States. Significant gains have been made with point source pollution. The effort to reduce nonpoint source pollution has proven more difficult. It is almost as difficult to study nonpoint source pollution as it is to control it. Data on development activity and on chloride concentrations suggest that nonpoint source pollution will continue to be a management challenge. Since 1988, nonpoint source pollution has been the main target of watershed management. It will continue to be the thrust of both management and monitoring, particularly in light of the fact that sedimentation is almost exclusively a nonpoint source problem.

POSSIBLE STRATEGIES FOR A NEW WATERSHED MANAGEMENT PLAN

Following is a menu of options for consideration in updating the watershed management plan. Not everything on the list could or should be done. The items on the list must be evaluated based on effectiveness, cost, feasibility, and other factors. However, the list is a starting point to updating the watershed plan.

Sedimentation

- Expand on the current partnership with the Thomas Jefferson Soil and Water Conservation District to make progress on this shared mission. Consider providing local/utility funds to enhance TJSWCD efforts focused on SFRR problems.
- Promote riparian buffers:
  - Encourage farmers in the SFRR Watershed to enter the Conservation Reserve Enhancement Program (CREP) and other agricultural cost-share programs.
  - Add to federal and state funds with utility funds to bring more farmers into the program.

    - Use local/utility funds to purchase riparian easements, with the help of the TJSWCD, for the expected life of the reservoir.
    - Increase enforcement of the Albemarle County riparian buffer ordinance on previously developed land. Current enforcement focuses on new development and complaints.
    - Increase riparian buffer education efforts.
    - Require buffers by those who benefit from County programs such as ag/forestral districts, land use assessment, and the Acquisition of Conservation Easements (ACE) program.
- Maximize forest throughout the watershed.
- Launch a major research effort into the sources of and appropriate mitigation strategies for sedimentation. Outside sources would be used, but a significant local commitment would be essential.
- Work with agricultural agencies to encourage other best management practices (BMPs) that reduce sediment runoff.
- Conduct a visual assessment of erosion and other problems in watershed streams.
- Carry out stream bank stabilization at critical locations.
- Investigate forebays to trap sediment entering SFRR.
- Hire more Erosion and Sediment (E&S) Control inspectors in Albemarle County to increase enforcement of E&S law in the SFRR Watershed. (Currently there are three inspectors, two plan reviewers, and a supervisor in the E&S program.)
- Make the Albemarle County stormwater ordinance stricter in the SFRR Watershed and more directed at sediment.
- Develop a reservoir sediment load model as a management/regulatory tool.
- Consider the benefits and harms of private ponds. Such ponds can trap sediment but they also break up stream networks, destroy wetlands, and reduce water quality in several ways. The question of whether the benefits of ponds outweigh the benefits should be addressed to decide whether to promote or discourage them.

Nutrients / Enrichment

- Promote riparian buffers (including the same possibilities listed for sediment).
- Support agricultural agencies (TJSWCD, Natural Resource Conservation Service {NRCS}, Cooperative Extension Service, etc.) in promoting best management practices that reduce nutrients in runoff. Support could come in a financial form or through staff coordination.
- Work to prevent and prepare for an increase in septic system failures.
    - Assess the actual risk from septic system failures to calibrate the response. The threat to groundwater supplies may be greater than that to surface water supplies at least initially.
    - Work with the Virginia Department of Health (VDH) to educate the public regarding proper maintenance.
    - Work with VDH to apply enhanced treatment technology to problems when necessary. Adopt necessary zoning ordinance language.
    - Work with VDH to provide financial support for low income families with failing septic systems or in need of assistance to carry out maintenance.
    - Intervene to help develop solutions when an entire community faces a problem.

    - Consider an ordinance to assure proper maintenance.
- Prepare for increased land application of human biosolids and/or animal wastes.
    - Assure that phosphorus is not over-applied.
    - Consider a biosolids ordinance.
- Develop a pollution load model as a management/regulatory tool.

Pathogens and Toxins
- Initiate more outreach to homeowners on monitoring and maintenance of fuel oil tanks and the use of chemicals.
- Stay apprised of Virginia Department of Environmental Quality (VDEQ) efforts (such as the Leaking Underground Storage Tank and Virginia Pollution Discharge Elimination System programs) in the SFRR Watershed.
- Get involved with TMDLs in the Rivanna River Watershed in the interest of minimizing fecal coliform counts.
- Work with VDH to educate the public regarding proper use and maintenance of septic systems.
- Educate public on other aspects of pollution prevention (involving household hazardous waste, etc).
- Become more familiar with agricultural and residential uses of potentially hazardous chemicals.
- Work with agricultural agencies (TJSWCD, NRCS, Cooperative Extension Service, etc.) to assure proper use of potentially hazardous chemicals on farms.
- Perform monitoring for metals and other potentially hazardous materials as needed.
- Prepare (as described above) for increased application of biosolids.
- Encourage vegetated buffers on reservoirs, etc. to make them less hospitable to geese.

Other Issues
- Determine if the hydraulic conditions produced by the hydropower plant are allowing more time for algae nutrient consumption and growth resulting in larger algae populations and if those populations are causing problems. If so, carry out a cost benefit analysis of shutting down the power plant seasonally to reduce algae concentrations versus other methods of reducing disinfection by-products. Algae provide some of the organic material that reacts with chlorine to produce the by-products.
- As water quantity modifications to the SFRR are being designed, investigate whether measures to improve the water quality of the tailwater can be included.
- RWSA, County, and City could work with Virginia Department of Game and Inland Fisheries (VDGIF) to determine the best way to manage the voluntary release of water to the Moormans River below Sugar Hollow Reservoir in a way that does not threaten the water supply.
- Address concerns regarding the possible US 29 Western Bypass.
- Use the Water Protection Ordinance to prevent development of the SFRR shoreline. Clarify policies that support the ordinance and educate riparian landowners.

- Work with the Albemarle County Department of Parks and Recreation, VDGIF, rowing groups, and others to assure the recreation activities and facilities do not pose a risk to the SFRR.
- Consider abandoning the Lickinghole Basin pro rata share policy for the on-site BMP policy in place in most of the County, or consider use of subregional BMPs in the Crozet Designated Growth Area.
- Develop a zebra mussel education program and possible boat washing facilities and requirements.
- Determine a strategy for eliminating cows from the reservoir that is fair to the farmers using the reservoir.

Watershed Resilience

- Maximize forest throughout the watershed.
- Minimize fragmentation of the land and conversion of land to residential/commercial land use.
- Encourage farming practices that minimize impact to water quality.
- Promote riparian buffers (including the same possibilities listed for sediment).
- Protect land for water supply protection through Albemarle County's ACE program, the TJSWCD riparian easement program, the Virginia Outdoors Foundation, and other programs.
- Continue and expand efforts to implement the RWSA Board policy for managing the Buck Mountain Creek holdings, particularly in a way that protects the SFRR.

RECOMMENDATIONS FOR WATERSHED AND RESERVOIR MONITORING

The technical recommendations below are based on staff experience with water quality monitoring in the SFRR Watershed and elsewhere. They give particular attention to the issues that arose in preparing this report. Reinitiating and updating reservoir and watershed monitoring will be essential to evaluating the effects of an updated watershed management plan.

- Establish a relationship with a scientific body that can help with quality control, training, and data management. Possibilities include the University of Virginia, Virginia Tech, and the Occoquan Watershed Monitoring Laboratory. Such a relationship could provide consistency and quality control and a large scale perspective that is not possible in an isolated program. Previously this consistency was provided by a long-term relationship with a single consulting firm.
- Establish a minimum water quality monitoring program to be part of the Rivanna Water and Sewer Authority's (RWSA's) budget, rather than a soft money item.
- Keep enough elements of the previous water quality monitoring protocol to allow long term comparison on key issues.
- Develop a mechanism to feedback water quality monitoring results to watershed management.
- Develop a reporting procedure for water quality monitoring data.

- Monitor the reservoir <u>and</u> its tributaries to better establish relative contributions of pollutants from the tributaries.
- Coordinate with VDEQ water quality monitoring.
- Collect flow data with chemistry data where possible and safe.
- Carry out special investigations as needed.
  - Sample streams in areas of known septic system problems to understand possible related pollution loads.
  - Evaluate the flow paths approaching the SFRR dam under different conditions to understand the composition of the raw water and tailwater.
- Seek grant funding for large investigations.
- Develop a standard operating procedure (SOP) and quality assurance/quality control (QAQC) plan for monitoring and investigation efforts.
- Formalize data storage procedures.
- Make data readily available to other professionals and the public.
- Strengthen the link between compliance monitoring at the water treatment plant and watershed management monitoring.
- Establish links between professional watershed management monitoring for water supply protection and citizen monitoring for general ecosystem protection and education.
- Coordinate chemical and biological monitoring.
- Collect chlorophyll <u>a</u>, pheophytin, and total organic carbon to improve understanding of algae populations and organic material concentrations.

GLOSSARY OF TERMS AND ABBREVIATIONS

ACSA- The Albemarle County Service Authority is the public utility that provides retail sale of municipal water and collection of sewage in Albemarle County, VA.

BMPs- Best Management Practices. Practices intended to reduce environmental impacts of a land use.

cfs- Cubic feet of water passing through a stream cross section in a second. Units for measuring stream discharge (or flow). Equals approximately 0.65 mgd.

Conductivity- A measure of the ability of water to conduct electricity generally because of the presence of salts. It is used as a general indicator of pollution.

Discharge- Commonly called flow. The volume of water passing through a stream cross section per unit time.

Flow- Formally called discharge. The volume of water passing through a stream cross section per unit time. (Can have other meanings in other contexts.)

IRM- Integrated Resource Management is a process through which a range of related water issues such as water supply, quality, conservation, and environmental needs are considered together.

Load- A unit of a substance transported relative to time. For example, gallons of water (or tons of sediment) per year. Contrasts with a “yield”.

MCL- Maximum contaminant level. The highest level of a contaminant that is allowed in drinking water.

mgd- Millions of gallons per day. A common unit of drinking water use for a municipality. Equals approximately 1.5 cfs.

Nitrate and Nitrite- The sum of two compounds formed by the bonding of nitrogen and oxygen. These forms of nitrogen are highly soluble and easily taken up and consumed by plants.

ppb- Parts per billion or µg/liter. One minute in 2000 years or one penny in $10,000,000.

ppm- Parts per million or mg/l. One minute in two years or one penny in $10,000.

RWSA- The Rivanna Water and Sewer Authority is the utility that provides drinking water and treats sewage for the City of Charlottesville and County of Albemarle.

RWSA has two customers- the City and the ACSA. These customers distribute water to and collect waste water from rate payers.

Tailwater- The water released from a dam.

TMDL- Total Maximum Daily Load. A research and planning process required for stream segments that don't meet goals set under the Clean Water Act. The TMDL refers to the total amount of pollutant the stream segment can receive while meeting the water quality goal.

Total Phosphorus- The sum of all forms of phosphorus in the water.

Total Nitrogen- The sum of all forms of nitrogen in the water including nitrate and nitrite and others.

TJSWCD- The Thomas Jefferson Soil and Water Conservation District. A state body serving Albemarle and other nearby counties. TJSWCD works within the structure of the Virginia Department of Conservation but is directed by a publicly and locally elected board.

USEPA- The United States Environmental Protection Agency. The federal regulator of water quality.

VDCR- The Virginia Department of Conservation and Recreation. The state agency responsible for urban erosion and sediment control, stormwater management, certain aspects of watershed planning, and many other functions.

VDH- The Virginia Department of Health. The state agency responsible for drinking water quality.

VDEQ- The Virginia Department of Environmental Quality. The state monitoring and regulatory authority for streams among other things.

VDGIF- The Virginia Department of Game and Inland Fisheries. The state agency responsible for fish and game. This agency has a special interest in stream flow issues.

WPO- The Water Protection Ordinance is Chapter 17 of the Code of Albemarle County, VA. It comprises County laws regarding erosion and sediment control, stormwater treatment, and stream buffer protection.

Watershed- The area of the landscape from which all rain that falls drains through a common outlet such as the mouth (or any point) of a river.

Yield- A unit of a substance transported relative to watershed area and time. For example, gallons of water (or tons of sediment) per acre per year. Contrasts with a "load".

INTRODUCTION

The purpose of this report is to review the 36 year history of the South Fork Rivanna Reservoir (SFRR) and the 23 year history of active watershed management with an eye toward developing and implementing new watershed management approaches. The last watershed management plan for SFRR was developed in 1979 (F.X. Browne Associates, Inc. and Watershed Management Plan Committee 1979). The community is currently engaged in a *Water Supply Project* with a planning horizon of 50 years. All indications are that SFRR will remain the dominant water source for years to come (VHB 2001b, RWSA-CAC 2001).

It is time to revisit the 1979 plan in order to adapt to changes and develop new strategies to address the unsolved problems. The reservoir water quality issues are both different from and similar to those faced 22 years ago. Water quality, the watershed landscape, drinking water regulations, and watershed management techniques have all changed. At the same time, sedimentation rates and development rates have remained stubbornly persistent. The community must learn from and build upon the watershed management efforts of the past to avoid putting the SFRR at increased risk of water quality and quantity problems just as we are putting more emphasis on it as a water supply.

The SFRR is the largest water source for the 82,000 people using public water in the City of Charlottesville and urban Albemarle County (Figure 1). SFRR water is treated near the reservoir at the South Fork Rivanna Water Treatment Plant. Water for the urban system also comes from the Sugar Hollow Reservoir on the Moormans River near White Hall and the Ragged Mountain Reservoirs southwest of Charlottesville. Water from these reservoirs is treated at the Observatory Water Treatment Plant near the University of Virginia. The northern portion of Albemarle County's Designated Development Area is served by an intake on the North Fork Rivanna River with its own water treatment plant. Chris Greene Lake serves as a back-up supply for this plant. In the year 2000 SFRR provided 66.2% of the water used in the urban area (RWSA 2001). The remaining water came from the Observatory Water Treatment Plant (31.4%) near the University of Virginia and the North Fork Rivanna Water Treatment Plant (2.5%) north of Charlottesville.

There are several other water sources tapped in Albemarle County. Crozet receives water from the Beaver Creek Reservoir that is treated at a nearby plant. Both the Sugar Hollow and Beaver Creek Reservoirs and Watersheds are nested within the SFRR Watershed. Scottsville is served by a local source, the Totier Creek Reservoir, and a local water treatment plant. Residents of Albemarle County who are not served by public water use groundwater from private or community wells. Well users who live in the SFRR Watershed have an influence on the SFRR water. Their water comes from the same hydrologic system, though they do not drink SFRR water in their homes.

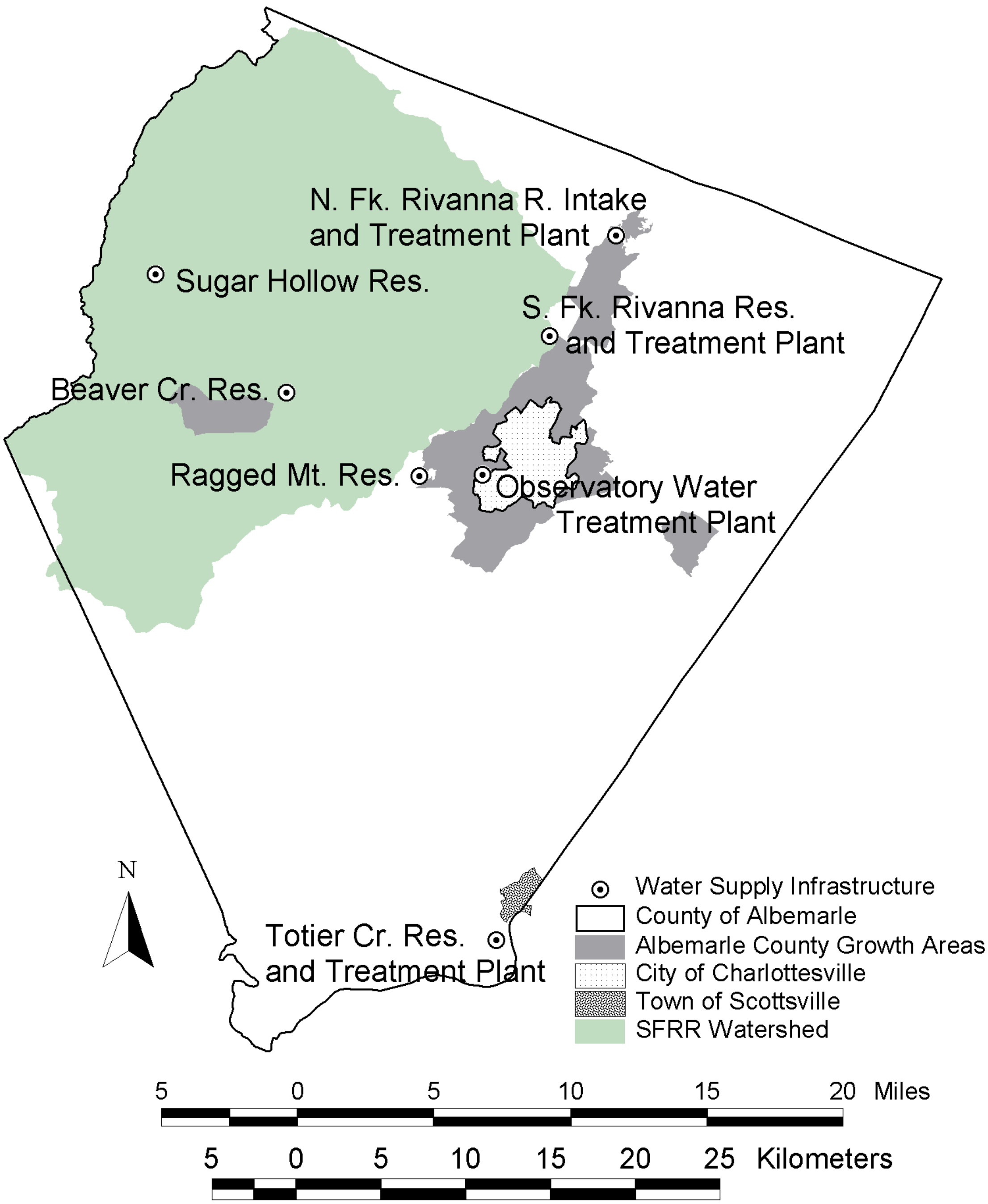


Figure 1. Major elements of the public water supply system for the City of Charlottesville and Albemarle County, VA. The City, County Designated Development Areas, and Town of Scottsville are served by public water.

The SFRR was filled in 1966. By the early 1970s, water quality problems in the reservoir were evident. Research, community debate, and discussion led to the watershed management plan in 1979. Since that time, the community has worked hard to protect water quality. Charlottesville/Albemarle has been one of the most progressive water protection communities in Virginia.

In an effort to understand the reservoir and track the results of management, water quality monitoring has been carried out on and off since 1975. Now there is enough data to reevaluate the condition of the reservoir, look at changes that have occurred, and try to assess the impact of water protection efforts. This report is the result of an extensive effort to collect and analyze data from Albemarle County, Rivanna Water and Sewer Authority, and Virginia Department of Environmental Quality efforts. (This document does contain technical information, but it is intended for a wide audience. A glossary of terms is provided.)

The document is arranged to provide ecological and historical background at the beginning, analysis of change in the middle, and ideas for updating the 1979 plan at the end:

- “South Fork Rivanna Character and Ecology” places the reservoir in the setting of its watershed and explains the major ecological processes at play. It is meant to provide the context for the issues discussed throughout the document.
- “Watershed Management History and Issues” outlines the major reservoir issues (crises in some cases) and the solutions the community has applied. It includes a reservoir history timeline. It also lists longstanding and new issues worthy of discussion.
- “Changes Over Time” contains the substance from the data analysis. It considers planning data on how land use management activities have played out and the results of water quality monitoring in the reservoir and its tributaries.
- “Updating the 1979 Watershed Management Plan” describes existing planning documents and tools available for watershed management.

This report is an attempt to apply science to management and policy issues. Science, like management, is an ongoing process. The interpretations here are based on the best data currently available and standard methods of analysis. Scientific interpretations are subject to modification as new data and better methods of analysis are applied. This report outlines the history of the reservoir water quality and the management issues as they appear today.

Finally, there are many factors that influence the quality of water that reaches the consumer. The raw water is made potable at the water treatment plant. It then travels through and extensive distribution system involving various tanks, pumps, and miles of pipe. Upon leaving the municipal distribution system it travels through the plumbing system of the consumer's home or business. While all these systems are connected, as are wide variety of water issues that concern the community, this report deals primarily with the conditions that effect the raw water up to the point where it is drawn into the water treatment plant. Sometimes this topic is called, “Source Water Protection” (which is a special field of Watershed Management). It may seem odd to isolate Source Water Protection from other water issues, but in practice it is a very large and complex topic worthy of its own report.

SOUTH FORK RIVANNA CHARACTER AND ECOLOGY

Introduction

In order to understand the impact of the 1979 South Rivanna Reservoir Watershed Management Plan and consider ways to update the plan, it is essential to understand the ecological underpinnings of the South Fork Rivanna Reservoir and Watershed. A watershed is an ecosystem. It is a physical “place” with patterns of energy and material exchange that distinguish it from other places. If there is any hope of managing specific aspects of the watershed, it will rely upon understanding of the ecological processes that characterize the system. Some of that character is the result of a set of unchangeable physical elements such as watershed size, rainfall, and geology. Other aspects have a strong cultural component such as land cover and pollution loads.

Watershed Size and Hydrology

The most striking characteristic of the SFRR Watershed is its size. The watershed is approximately 258 square miles. The surface of the reservoir is 390 acres (or 0.61 square miles). The resulting watershed to reservoir surface area ratio is 424:1. By contrast, the surface area ratios of five comparable reservoirs in the mid-Atlantic Piedmont range from 241:1 to 34:1 (Table 1).

The main benefit of a large watershed is that there is a large basin to catch rain and store groundwater to fill the reservoir. A relatively small storm can fill the reservoir during a dry period as occurred in August of 1999 after an extended drought. Also, baseflow from each of the large number of tributaries can keep the reservoir full well into a drought. In the fall of 2001 the reservoir filled during a period of no rainfall. This filling was at least partly the result of a reduction in plant transpiration after leaf-fall freeing soil water to supplement baseflow. With such a small reservoir relative to the watershed size, the bulk of storage is in the watershed groundwater rather than the reservoir pool itself.

Drawbacks of a large ratio include the fact that the relatively small reservoir can store only a small percentage of the water that enters the reservoir over a year. Also, a large watershed means that there is a large pollutant source and a large area to manage for pollution control and reduction.

Table 1. Reservoir size versus watershed size for the South Fork Rivanna Reservoir near Charlottesville, VA and comparison reservoirs in the mid-Atlantic Piedmont region (Post 2001, Scarpulla 2001).

Reservoir	SFRR	Occoquan (VA)	Manassas (VA)	Liberty (MD)	Loch Raven (MD)	Prettyboy (MD)
Watershed Area (square miles)	258	573	75	163	303	80
Reservoir Surface (square miles)	0.61	2.38	1.09	4.84	3.75	2.34
Watershed to Reservoir Surface Ratio	424:1	241:1	69:1	34:1	81:1	34:1

The extensive watershed area delivers a large amount of water. An average 45 inches of rain falls on the SFRR's 258 square mile watershed in a year, translating into approximately 204,000 million gallons of water (Table 2, USDA 1985). The majority of the rainwater evaporates or is transpired by plants back to the atmosphere. Some water is removed from the SFRR watershed via two smaller reservoirs that are nested within it, the Sugar Hollow Reservoir and Beaver Creek Reservoir (Table 2). Still, a large volume of water reaches the reservoir. Because of the small size of the reservoir relative to the watershed, most of the water that reaches the reservoir, over 90%, passes through (Table 3).

On average, the bulk of the water that reaches the SFRR is the result of storm flow (Table 2). Under storm conditions, an even larger portion of the water exits the reservoir without being stored. Also, storm events bring larger loads of pollutants than normal flow because of the action of the rain on the landscape and the power of the high flows eroding the stream banks. Though most of the stormwater volume passes through the reservoir, much of the pollutant load remains in the reservoir.

During periods of low rainfall, the reservoir is sustained by baseflow from groundwater (Table 2). Groundwater from the watershed essentially supplements the storage capacity of the reservoir.

Though drinking water quality is influenced by all the water that reaches the reservoir, only a small portion of the water is consumed. In the year 2000, the Charlottesville/Albemarle community consumed 2,600 million gallons of SFRR water (Table 3). If this consumption occurred in a typical year (based on the long-term hydrologic record) it would amount to 1.3% of the rainfall in the watershed and 3.5% of the water reaching the reservoir.

Table 2. Estimate of the water falling on the South Fork Rivanna Reservoir Watershed (near Charlottesville, VA) and the destinations of that water (Carter et. al. 1985, USGS 1999).

		Millions of Gallons per Year	Percentage of Total Rainfall
Water Source	**45 inches of rain on 258 square miles**	**204,000**	**100**
Water Destinations	Evaporation, transpiration (by plants), or long term storage in the groundwater	128,000	62.7
	Withdrawal from watershed via Sugar Hollow reservoir*	1,460	0.7
	Withdrawal from watershed via Crozet sewage interceptor and losses^	225	0.1
	River flow to reservoir	74,400	36.5
	River flow to reservoir as storm flow+	*38,900*	*19.1*
	River flow to reservoir as base flow+	*35,500*	*17.4*

* This estimate reflects the maximum possible withdrawal of four million gallons per day. The withdrawal is less when the reservoir pool is low, water is directed to Ragged Mountain Reservoir rather than Observatory Water Treatment Plant, or maintenance is underway.
^ Water for Crozet is withdrawn from Beaver Creek Reservoir in the Mechums River Watershed. Much of it is transported out of the SFRR Watershed via the Crozet Sewage Interceptor. This estimate is based on the year 2000 usage of 0.615 million gallons per day in Crozet. It includes usage for the ConAgra plant (since closed) and associated industrial losses of water from the watershed.
+ Base flow separation based on Hewlett and Hibbert 1967 and Wiley 1997.

Table 3. Estimates of the destination of water that reaches the South Fork Rivanna Reservoir near Charlottesville, VA (USGS 1999, RWSA 2001).

	Millions of Gallons per Year	Percentage of Flow into Reservoir	Percentage of Rainfall in Watershed
Evaporation from reservoir surface	1,740*	2.3*	0.9*
Passing over dam, through hydropower plant, or through mud gates	70,100*	94.2*	34.4*
Consumed by community in year 2000	2,600	3.5*	1.3*

*These values are based on applying year 2000 consumption data to long term hydrologic records as opposed to applying year 2000 consumption data to the year 2000 hydrologic record. In a drought year, the percentage consumed would be higher both because less rain would fall and more consumption (particularly outdoor watering) would occur.

Watershed Location, Tributaries, and Land Cover

Another striking characteristic of the SFRR Watershed is that it falls almost entirely in Albemarle County (Figure 2). This fact means that the fate of the drinking water for Charlottesville and Albemarle is largely in the local community's hands (within the limits of state enabling legislation). Finding such large water supply watershed almost wholly within one jurisdiction is rare.

The SFRR Watershed can be divided into five major subwatersheds. From the largest to smallest they are: Mechums River, Moormans River, Buck Mountain Creek, Ivy Creek, and a set of small tributaries on the reservoir margin (Figure 3, Table 4). Each has distinctive geology, soils, and topography that have led to differences in vegetation and land use (Table 4). The land cover and land use of the entire watershed determine the water quality in the reservoir. These topics are discussed throughout this report.

One major cause of the impact of land use change on waterways is impervious cover. As watersheds are developed, more roofs, parking lots and roads are put in place. Such surfaces are completely impervious. These surfaces cannot absorb most of the water that previously soaked into the ground to be taken up by plants, recharge the deep groundwater, or maintain stream baseflow from the shallow groundwater. Instead the rainfall that is not soaked up becomes storm flow. It then can contribute to erosive conditions, transport sediment, and damage stream habitat. Large storm flows are associated with high pollutant loads. A rule of thumb is that stream communities decline dramatically when the amount of completely impervious land cover is about 10% of watershed area (Schueler and Holland 2001).

Data are not available to estimate accurately, but the amount of complete imperviousness in the SFRR Watershed is probably less than a few percent (RRBR 1998). Specific subwatersheds, especially small ones in developing areas, may approach or exceed the critical level of 10%, but the watershed as a whole does not. Still, as will be discussed later, the SFRR system may be very sensitive to any factor that might increase stream bank erosion.

A measure called, "effective impervious cover" can be used as a summary statistic for land use. Data are available describing effective impervious cover in the SFRR Watershed (RRBR 1998). In contrast to "completely impervious cover," effective impervious cover accounts for partially impervious land cover. Such land uses reduce the ability of the ground to absorb water without eliminating permeability entirely. Croplands and pastures are less permeable than forests because of compaction and other changes in soil structure (Kirkby 1978). Partial impervious cover can have similar effects to the effects of completely impervious cover at a lower level of intensity. While the effects may be less intense, the land uses may be more widespread. Effective impervious cover can be thought of as the percent of the watershed that would be completely impervious if the impact of partial impervious land was concentrated and added to the existing completely impervious land cover. Alternatively it can be thought of as the condition of the watershed on a scale ranging from completely forested (0% impervious) to completely paved (100% impervious).

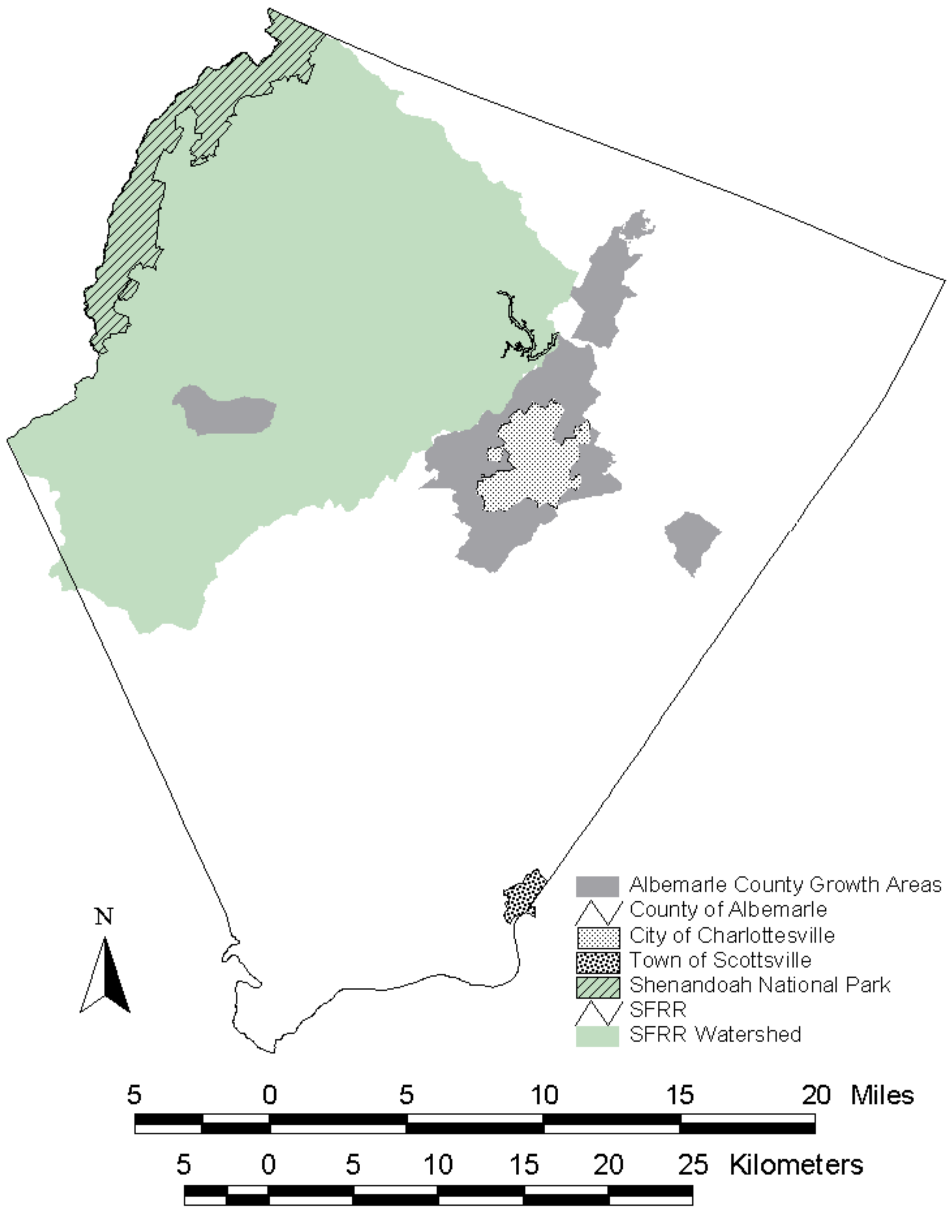


Figure 2. Location of the South Fork Rivanna Reservoir (near Charlottesville, VA) in Albemarle County, VA.

The effective impervious cover was calculated for the entire Rivanna River Watershed, including the SFRR Watershed, using data from the early 1990s (Table 5, RRBR 1998). The most intensive land uses (as reflected in the percent of effective imperviousness) are in the Ivy Creek Watershed (7.8%), which enters the reservoir closer to the water intake than the other major tributaries, and the small tributaries adjacent to the reservoir (7%, RRBR 1998, Table 5). These watersheds are close to Charlottesville, the urban road system, and County Designated Development Areas. By contrast, the Moormans River subwatershed, much of which is in Shenandoah National Park, has a much lower effective imperviousness (3.6%, RRBR 1998, Table 5).

It may not only be current land use that requires consideration. There is some evidence that historic land use is a major factor in modern problems, particularly sedimentation (Commonwealth of Virginia 2000). During the 19^{th} Century the region largely was denuded of trees (Trimble 1974). The lack of tree cover resulted in tremendous erosion. Stream flow transported some of the eroded sediment to sea, but a large portion was deposited temporarily in the stream valleys (as floodplain sediment). Today with a much more forest cover, landscape erosion may be less, but the large volume of sediment stored in the stream valleys is being resuspended via stream bank erosion.

Table 4. Land cover data for the South Fork Rivanna Reservoir Watershed (near Charlottesville, VA) and its tributaries (USEPA 1992).

	Buck Mt. Cr.	Ivy Cr.	Mechums R.	Moormans R.	Small Tributaries Along SFRR	SFRR Total
Total Area (Square Miles)	36.1	29.7	98.6	77.6	15.5	258
Developed (%)	0.4	4.2	1.7	0.2	3.1	1.4
Agricultural (%)	25.6	35.9	26.9	13.7	30.9	24.0
Forest (%)	73.2	59.0	69.9	85.4	60.4	73.2
Wetland (%)	<0.1	0.1	0.1	<0.1	0.2	0.1
Barren (%)	0.5	0.1	0.7	0.3	0.6	0.5
Water (%)	0.3	0.6	0.7	0.4	4.8	0.8

Table 5. Effective impervious cover data for the South Fork Rivanna Reservoir Watershed (near Charlottesville, VA) and its tributaries (RRBR 1998).

	Buck Mt. Cr.	Ivy Cr.	Mechums R.	Moormans R.	Small Tributaries Along SFRR	SFRR Total
Effective Impervious Cover (%)	5.5	7.8	6.5	3.6	7.0	5.7

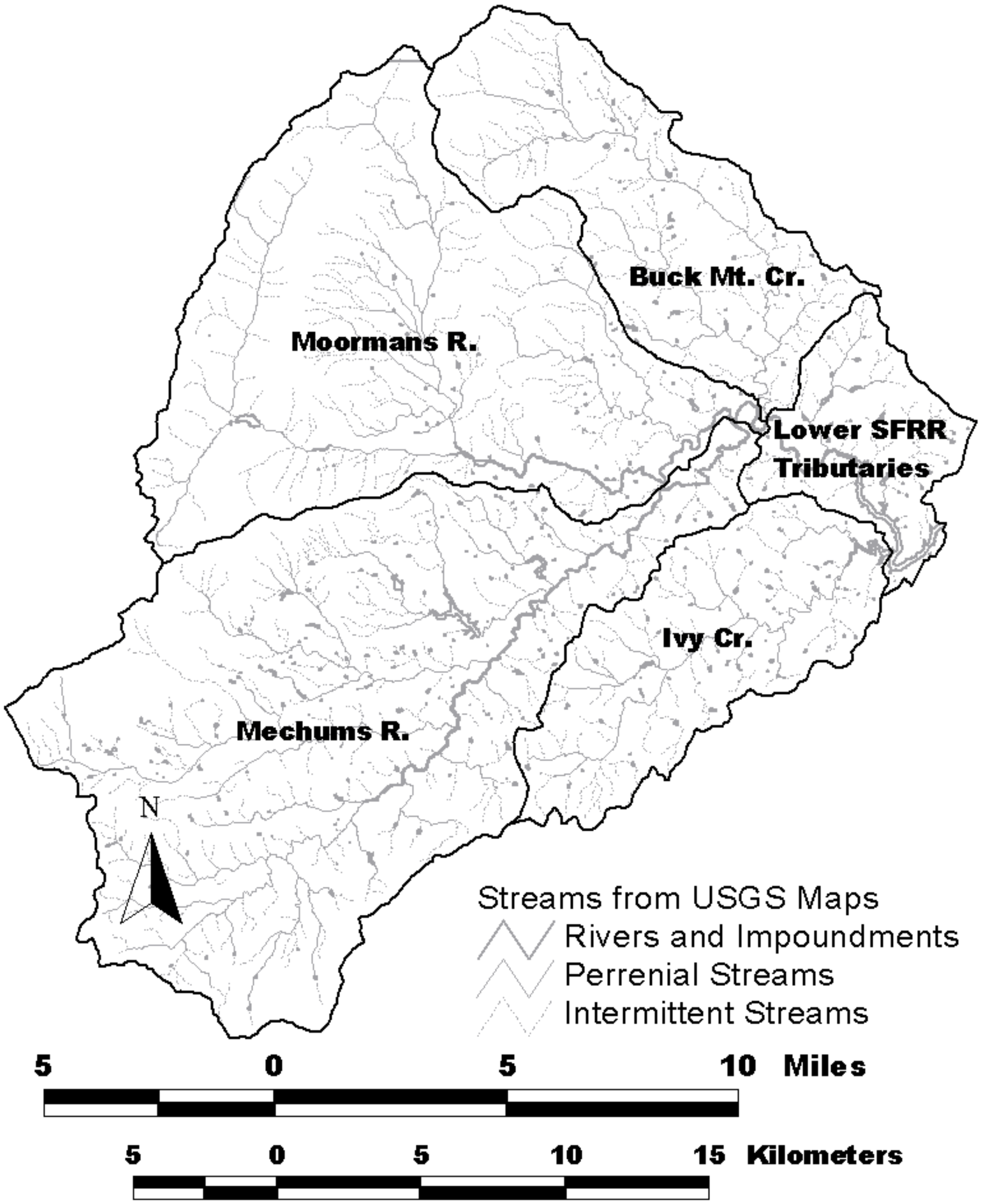


Figure 3. Sub-watersheds of the South Fork Rivanna Reservoir Watershed near Charlottesville, VA.

Reservoirs and Residence Time

The primary purpose a reservoir, increasing the residence time of the water, is the primary cause of the water quality problems many reservoirs present. The SFRR is no exception. In rivers, water passes by any one point relatively quickly. Impounding river water in a reservoir extends its residence time. The stretch of river that is now the SFRR probably had an average water residence time well under a half a day. The SFRR has an average residence time of six to eight days (Betz Environmental Engineers, Inc. 1977). Residence time would be shorter during storms and longer during low flows. On average, however, the water stays in residence (or is stored) long enough to be used as drinking water but also long enough for several ecological processes to occur. The SFRR increased residence time provides opportunity for sediment to be trapped in the reservoir, for algae to take advantage of nutrients in the river water and expand their populations, for the water to warm up and lose oxygen effecting habitat in the reservoir and downstream.

While most of the problems with reservoirs stem from the simple fact that they impound water, problems are enhanced by cultural factors. More sediment in the tributaries translates into more sediment available to settle in the impoundment. Higher nutrient concentrations in the tributaries serve as more food for algae. The nuances of these problems are discussed in following sections.

Riverine Characteristics of SFRR

Ultimately, SFRR is neither a river nor a lake (Figure 4). In important ways it falls in between the two designations. Some lakes and large reservoirs have residence times of more than a year. A very visible sign of the riverine nature of SFRR is the fact that it carries fine sediment like a river during storms. The reservoir, like the tributaries that feed it, is quite turbid following storm events. (Even so, a great deal of sediment settles in the reservoir.)

Another example of the riverine aspect of SFRR is the fact that mixing of the water as the result of storms sometimes breaks the pattern of temperature stratification that is typical of lakes in the summer. During the summer in classic lake stratification, cool water, which generally is denser than warm water, sinks beneath the warm water. The warm surface water only gets warmer as summer progresses resulting in distinct layers of water of sharply differing temperature. In fall, the surface water cools. Once the surface water drops below 39 degrees F, it becomes more dense than the water near the bottom and sinks resulting in “turnover”. Associated with temperature stratification there is usually stratification of dissolved oxygen or DO (discussed below).

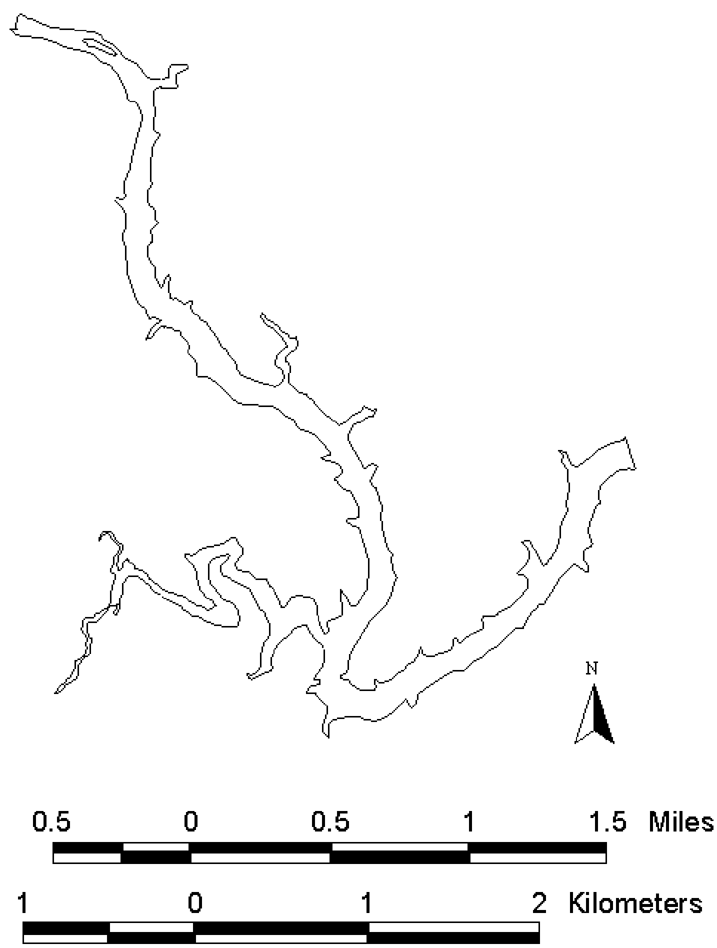


Figure 4. Outline of the South Fork Rivanna Reservoir near Charlottesville, VA.

Unlike in a classic lake, mixing in the SFRR is not restricted to only a water temperature trigger. The SFRR is definitely subject to temperature stratification and associated dissolved oxygen problems in summer (Figure 5). However, because the SFRR is riverine in nature, it is subject to high flows during large rain events and can mix due to the action of those high flows. Thus stratification is triggered by temperature conditions, but mixing can occur as a result of either storms or temperature conditions. At the height of summer, stratification may be maintained for some time, eliminated or reduced by a storm, and restored after mixing. Some storms may mix the upper reservoir but not the lower reservoir near the dam. During late fall, winter, and early spring the reservoir may remain well mixed (no data are available). Ultimately, though stratification is an important aspect of SFRR ecology, the stratification period of SFRR is often shorter and less consistent than that of a classic lake (Figure 5).

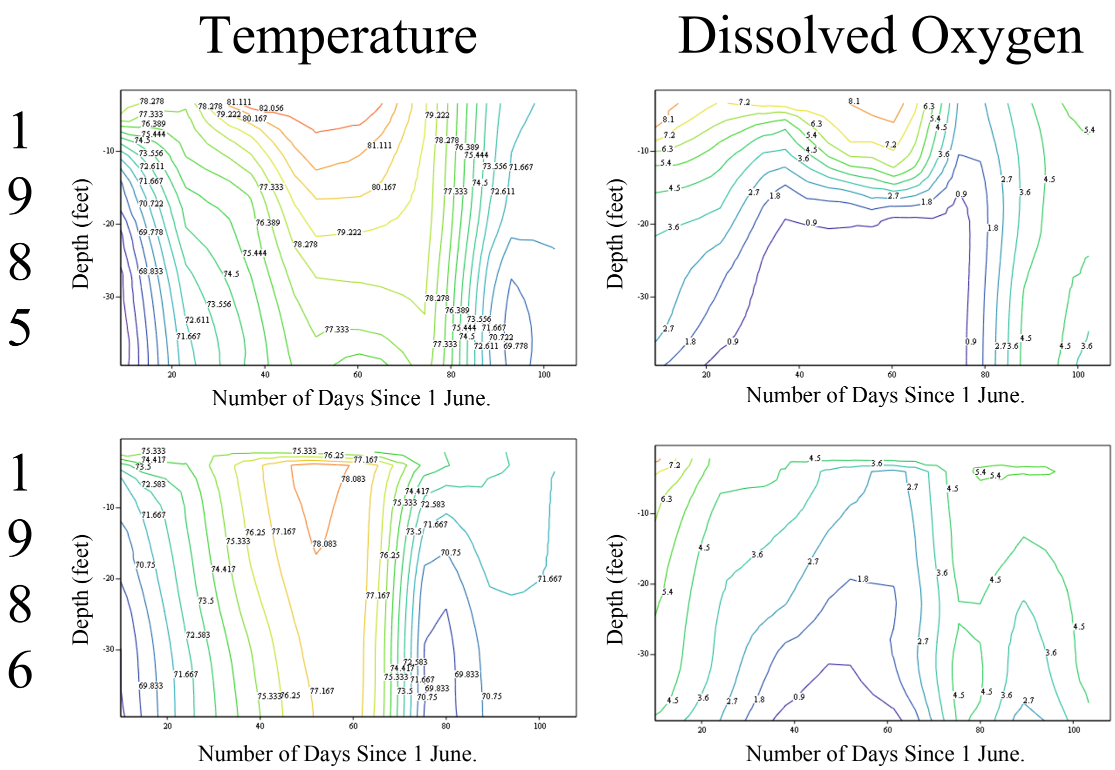


Figure 5. Temperature and dissolved oxygen profiles for the South Fork Rivanna Reservoir (near Charlottesville, VA). 1985 displays classic stratification through the summer. 1986 displays periods of mixing during the summer. Depth is on the vertical axes of each plot with the greatest depth near the bottom. The horizontal axes represents time (number of days past 1 June of each year). The lines within each figure represent temperature or dissolved oxygen isopleths in a manner much like a weather map.

Sediment Accumulation

The SFRR is filling with sediment at an overall average of 15.6 million gallons per year (Potter 2001a). In other words, 0.92% of the original reservoir volume is lost on average per year. It was originally predicted that SFRR would fill with sediment at an average rate of 19.6 million gallons per year (Potter 2001a).

The sediment is carried from the watershed by the energy of the tributary flow. This energy is most easily visualized as the water's velocity. In creating the several day residence time for water storage, velocities are greatly reduced. A side effect of the low velocities in the SFRR (and all reservoirs) is the deposition of tributary sediment. The larger the sediment particle, the more energy (or velocity) it takes to keep it moving in the water. The large sediment particles (sands) drop out very soon after they enter the slow moving environment of the reservoir. This phenomenon explains why the reservoir is only a few feet to inches deep under the Rheas Ford Bridge. Smaller particles make it farther into the reservoir. The smallest particles (clays and small silts) may pass through the reservoir and head down river, especially during storms. Particles that reach the dam contribute to high levels of suspended solids there and low water clarity (Table 6). SFRR has high suspended solid concentrations and low water clarity near the dam relative to comparison reservoirs. This turbidity is removed in the water treatment process and reflects the high sediment both to and through the reservoir. Storms bring higher sediment loads into the reservoir. Additionally, because the SFRR is somewhat riverine in nature, storms can increase velocities within the reservoir leading to redistribution of sediment farther into the reservoir.

Table 6. Typical median total suspended solids in the South Fork Rivanna Reservoir (near Charlottesville, VA) and comparison Piedmont Virginia reservoirs (Post 2001). Samples taken at the surface near the dam in the summer.

Reservoir*	SFRR	Occoquan (VA)	Manassas (VA)
Total Suspended Solids at the surface near the dam (ppm).	8	2.95	2.84
Water Clarity (Secchi Depth, inches).	43	55	56

Surprisingly, the sources of the sediment are not well understood. Sediment transport by streams is a natural process. Over geologic time this process has worn down the mountains, built up the Atlantic shelf, and created floodplains in between. Many human activities accelerate sedimentation.

A portion of sediment comes off the landscape. On the landscape, when rain falls, the energy of the raindrops and the energy of the water flowing over the landscape can displace soil particles and transport them from the landscape to the waterways. This process is called "landscape erosion." A forest allows only a small amount of erosion of sediment. This amount is estimated as 24 tons/square mile/year nationally according to the USEPA (VDCR 1992a). Grassland erosion is estimated to be an order of magnitude higher (240 tons/square mile/year). Cropland erosion is estimated to be yet another order of magnitude higher (4,800 tons/square mile/year). Construction erosion is estimated to be still another order of magnitude higher (48,000 tons/square mile/ year). Of course, cropland, grassland, and forests are present on much more land than active construction. Both the amount of land in any land use and the sediment yield of that land use need to be taken into account in estimating its impact. Also, human effort to minimize erosion can reduce the impacts. As required under state law, Albemarle County has a regulatory role in reducing erosion from construction sites. State and federal agencies have limited funds to encourage farmers and foresters to voluntarily reduce erosion from agricultural and forestry operations.

Table 7. National estimates of sediment yields based on land cover (VDCR 1992a).

	EPA Sediment Yield Estimate (tons/sq.mi./year)^
Forest	24
Grassland	240
Cropland	4,800
Construction	48,000

Overall, the SFRR Watershed is susceptible to landscape erosion, particularly where the forests have been removed (Table 6). This vulnerability is due to a combination of steep slopes, moderately erodable soils, a large watershed, and a relatively large amount of annual rainfall (Figure 6, Figure 7).

Sediment not coming directly from the landscape comes from stream bank erosion. As with landscape erosion, stream bank erosion is greatest during storms. The energy of the high flows in the streams works on the banks causing erosion. The same energy transports the sediment particles downstream to the reservoir. The sediment that composes the stream banks can be old bedrock that rotted in place (saprolite), but it is usually landscape sediment that previously was deposited in the floodplain. One hypothesis holds that near complete deforestation of the region in the 18th and early 19th centuries led to extreme landscape erosion (Commonwealth of VA 2000). The sediment loads were so great that the streams lacked the energy to transport all the sediment out of the region quickly. As a result, the sediment was deposited in the stream floodplains. Under this hypothesis, reforestation may have reduced landscape erosion, but the historic floodplain sediment is now being transported downstream. The SFRR (and its low water velocity) falls along the path to the sea.

Nobody knows whether the landscape or the stream bank is the dominant sediment source (TJWRAC 2001). Studies in some areas have shown stream banks to be the source of more than two thirds of the stream sediment (Center for Watershed Protection 2000). In other areas the stream bank load has been shown to be minor. The James River Tributary Strategy discusses the issue (Commonwealth of VA 2000). The authors speculate that the stream bank source may explain high sediment yields from the central Piedmont region of the James River basin. One researcher has found evidence that a highly disproportional sediment load comes from a particular geologic deposit along the Mechums River that falls roughly between Interstate 64 and State Road 250 (Sobeck 1998).

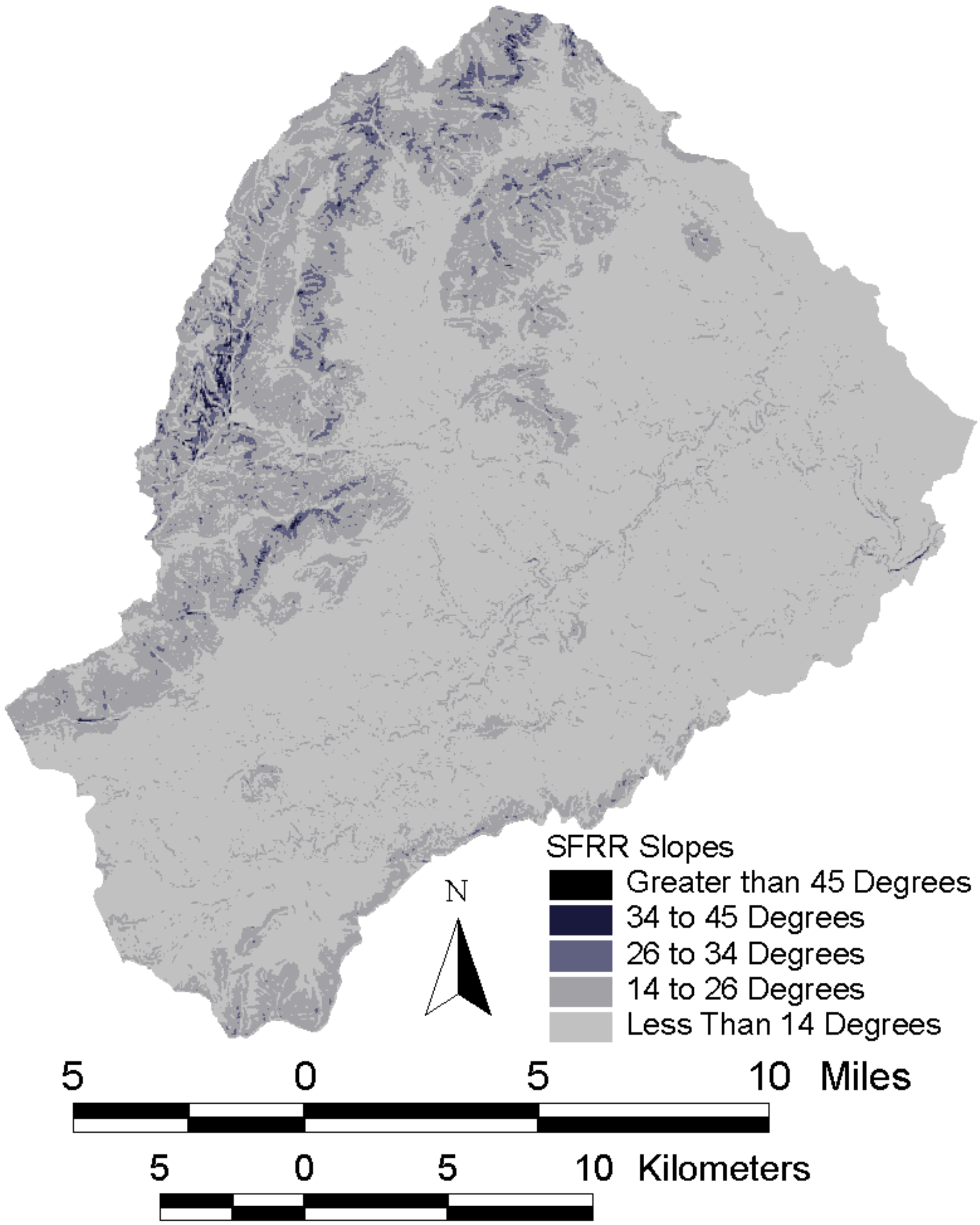


Figure 6. Slope steepness in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (Morgan et. al. 2000).

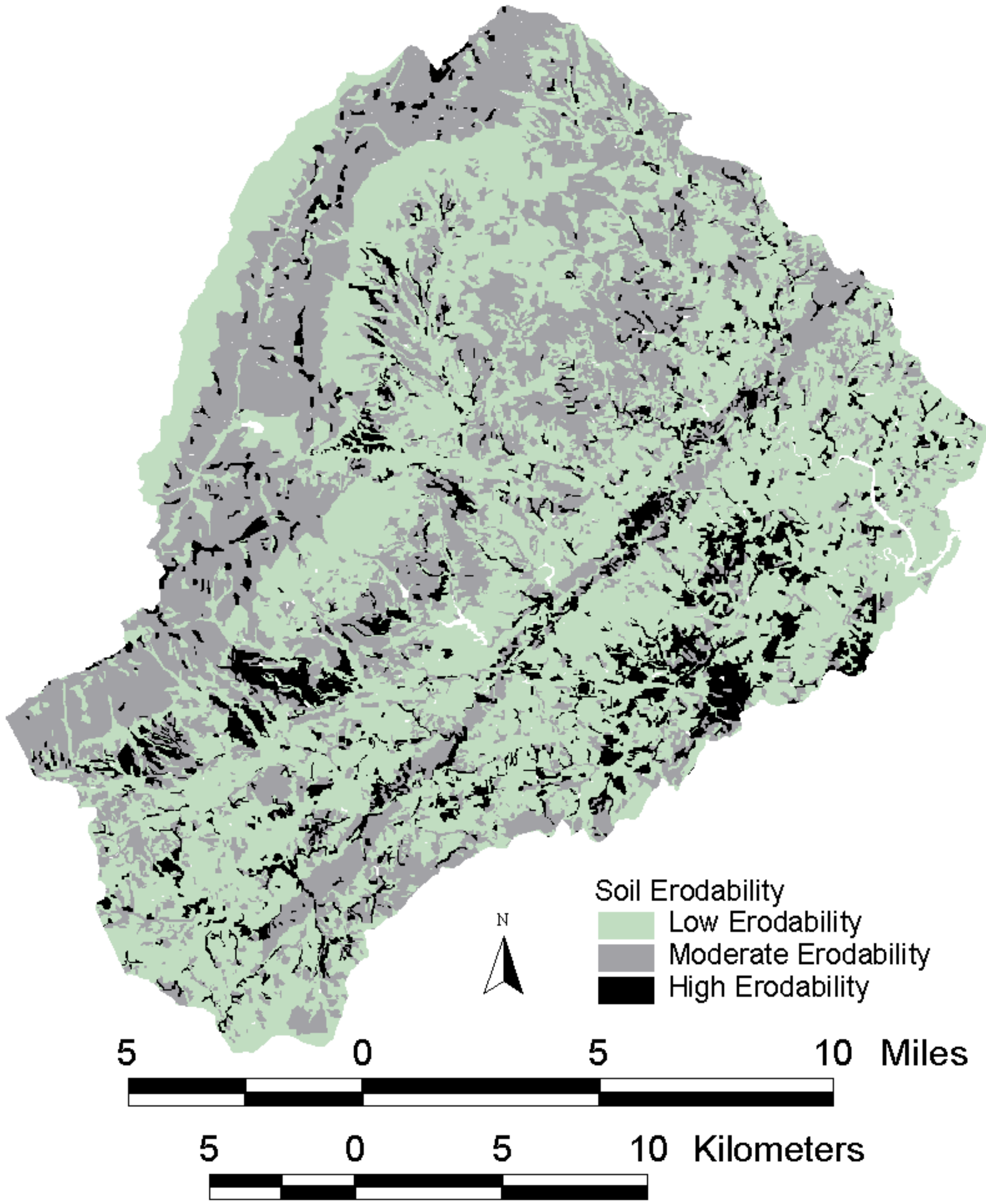


Figure 7. Soil erodability in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (Carter et. al. 1985). Interpretation based on the K factor (low = less than 0.23, moderate = 0.23-0.36, high = greater than 0.36; VDCRb 1992).

Anecdotal evidence suggests the importance of the stream bank source. Eroded stream banks are ubiquitous throughout the SFRR Watershed. A survey of 183 stream crossings in the 1970s revealed that 43% had bank erosion (F.X. Browne Associates, Inc. and Watershed Management Plan Subcommittee 1979). A 2001/2002 stream assessment of 20 miles of streams in the Crozet Designated Development Area (within the SFRR Watershed) revealed approximately 15% of the stream channel having significantly eroded banks on one side or the other (Albemarle County Department of Engineering and Public Works 2002). Overall, the SFRR Watershed has at least 764 miles of streams. If the same percentage applies to the entire SFRR Watershed, one would expect more than 115 miles of river and stream with significant erosion. Considered on the scale of the entire watershed stream network, there is a vast amount of stream bank erosion. By contrast, active construction, the worst source of landscape erosion, covers only a very small portion of the watershed at any one time and over 70% of the watershed is forested. Stream bank sediment also could explain the lack of success (at the watershed scale) of sediment reduction strategies that are oriented primarily at the landscape.

Over-Enrichment (Eutrophication)

A primary concern regarding water quality in the SFRR is cultural eutrophication. Eutrophication is a natural process associated with the succession or aging of lakes. It is a process in which increases in nutrients and/or increased sensitivity to nutrients result in ecological changes in a lake. Cultural eutrophication is eutrophication caused by human induced increases in nutrients. Eutrophication of flowing water is rare because the short residence times give the nutrients little time to affect the local ecosystem. Impoundments, which (by design) greatly increase the residence time, allow the nutrients to have greater effect. Thus, impounding water often (if not usually) leads to some degree of eutrophication. Human activities that add nutrients to the tributaries beyond the natural, background levels further increase cultural eutrophication of reservoirs.

The term eutrophication describes an ecological process. Nutrients are food for algae floating in the reservoir. With increased food, the algae population increases. A large algae population can create problems. During the day, algae both release oxygen (via photosynthesis) and consume it (via respiration). During the night they only consume oxygen. Large algae populations can lead to low oxygen concentrations at night. (SFRR fish kills in the early 1970s occurred at night.) Furthermore, when floating algae die, they sink to the bottom where they are eaten by bacteria. Bacteria consume oxygen (also via respiration). The result can be very low oxygen conditions in the reservoir, particularly at lower levels that are isolated from the air by temperature stratification. The low oxygen conditions can foster chemical reactions that change iron and manganese from forms that settle on the bottom to forms that dissolve in the water column. The resuspension of the iron and manganese can lead to problems with the taste, odor, and appearance of the water. (These aesthetic problems are not associated with health safety problems.) Also, certain types of algae cause taste and odor problems or clog filters in the water treatment plant. Such algae are favored by eutrophic conditions.

The nutrient that tends to limit the algae growth in most freshwater systems including the SFRR is phosphorus. In other words, this is the food that algae are most likely to not have enough of to increase their population. When food is the limiting factor (as opposed to physical or biological factors), adding phosphorus will increase algae growth. The mean nitrogen to phosphorus ratio for the reservoir is 53:1 (Figure 8). If nitrogen were the limiting nutrient, the ratio would be less than 16:1 (Redfield 1958). Under rare conditions, ratios have been less than 16:1, but phosphorus is almost always the more important nutrient.

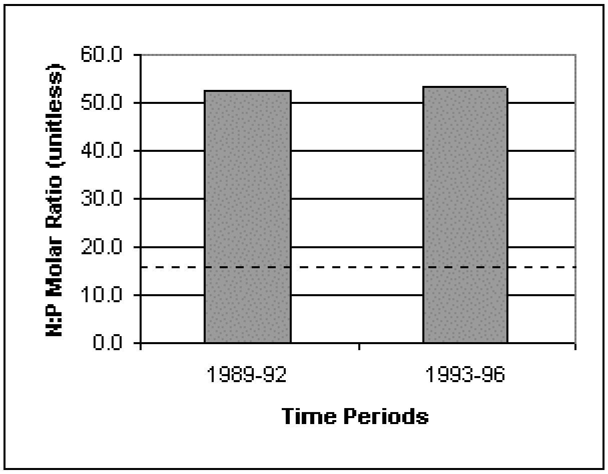


Figure 8. Nitrogen to phosphorus ratios at the surface and near the dam in the South Fork Rivanna Reservoir near Charlottesville, VA. A ratio greater than approximately 16 (dashed line) indicates that if nutrients limit the algae population, phosphorus is the likely limiting factor (Redfield 1958).

Phosphorus is a naturally occurring element found in rocks, soils, plants and animals that is also a product of human activities. It tends to travel bound to sediment but can travel in dissolved forms. Phosphorus loads to the reservoir are the result of many activities in the SFRR Watershed including farming, development, forestry, and human waste disposal. Farming contributes phosphorus through erosion, fertilizer runoff, and animal waste. Development contributes phosphorus during construction through erosion and after construction through erosion, lawn fertilizer runoff, and pet waste. Forestry contributes through erosion and fertilizer runoff. Phosphorus is a component of human waste (a result of being a component of human foods) and of some human waste products such as food waste and some detergents. Thus phosphorus enters the watershed through septic fields and sewage treatment facilities.

While not surprising, the finding that phosphorus is the limiting nutrient is important because many management efforts, including Albemarle County's Water Protection Ordinance, target phosphorus as the "keystone" pollutant. A keystone pollutant is one that is chosen as a focus in order to simplify the regulatory regime. It is chosen based on the assumption that it is a particularly important pollutant. Also, it is assumed that the same strategies that reduce loads of the keystone pollutant will reduce loads of other important pollutants. Because most phosphorus travels bound to sediment, reducing phosphorus usually means reducing sediment. Many pollution sources release both phosphorus and nitrogen, so controls directed at phosphorus can address nitrogen to some degree.

Though not generally limiting in the SFRR, nitrogen is of concern. Nitrogen tends to be a problem in marine and estuarine environments like the Chesapeake Bay. Many sources of nitrogen are similar to those of phosphorus. Nitrogen is also delivered via atmospheric deposition both directly to the reservoir and via the watershed. Thus, in contrast with other sources, much of the atmospheric nitrogen comes from outside the reservoir watershed. Atmospheric nitrogen is a result of automobile and power plant emissions. In the Chesapeake Bay Watershed generally, atmospheric deposition is believed to account for 15 to 25% or more of all nitrogen reaching the Bay (Horton and Eichbaum 1991). Another important difference between the two major nutrients is that nitrogen tends to travel dissolved in water, while phosphorus more often travels bound to sediment.

Relative to comparable reservoirs in the mid-Atlantic Piedmont region, SFRR historically has elevated phosphorus levels and intermediate levels of nitrogen (Table 8). SFRR algae populations, represented by chlorophyll a (a compound required for photosynthesis), are similar to two of the comparison reservoirs, but much higher than three others (Table 8).

Table 8. Data on enrichment variables for the South Fork Rivanna Reservoir (near Charlottesville, VA) and comparison reservoirs in the mid-Atlantic Piedmont region (Post 2001, Scarpulla 2001). Data are median values of summer surface water samples taken in front of each dam over several years.

Reservoir	SFRR	Occoquan* (VA)	Manassas (VA)	Liberty (MD)	Loch Raven (MD)	Prettyboy (MD)
Total phosphorus (ppm)	0.034	0.03	0.02	<0.01	0.02	0.017
Total Nitrogen (ppm)	0.80	2.01	0.54	No data	No data	No data
Nitrate and Nitrite (ppm)	0.13	1.36	0.03	1.89	1.24	1.83
Chlorophyll a (ppb)^	10.34	11.42	11	1.21	2.96	3.48

*The Occoquan Reservoir has a sewage treatment plant releasing directly into it.
^ Some of the differences between the Virginia and Maryland reservoirs may be due to watershed geology and some due to land use.

In some water bodies, eutrophication is a significant source of sedimentation. The algae and the rooted plants construct themselves from carbon dioxide from the atmosphere and other materials present in the water. When the plants die, their bodies, including all the materials they have sequestered, can sink to the bottom and become part of the sediment. It is not known to what degree this process adds to sediment accumulation in SFRR. The river-like forces in the SFRR may wash most of the relatively light plant debris out of the reservoir and, as mentioned above, bacteria break down much of the plant material. The portion of plant-based sediments is probably very small compared to the portion of mineral sediments delivered from the tributaries and land along the SFRR.

Pathogens

Pathogens are not a problem in the water produced from the SFRR though they are a fundamental concern in drinking water protection anywhere. There are many human pathogens that can be present in the wild that are not acceptable in significant concentrations in finished drinking water. Pathogens are microbes that can cause illness in humans. They can be bacteria, parasites, or viruses (AWWA 1999). Pathogens can be introduced through animal (including human) waste in the watershed. The level of pathogens often is estimated by measuring the amount of total coliform bacteria in the water. This measurement is merely an approximation of pathogen levels because coliform bacteria are not necessarily pathogenic to humans.

SFRR raw water is treated by settling out solids with the assistance of chemicals, removing additional solids in a sand filter, and chlorinating. Pathogens come out with the solids in settling and filtering. Chlorination kills additional pathogens and serves to protect the water as it travels through the distribution system. The treatment plant is very successful at treating the raw water from SFRR. The year 2002 "Urban Service Area Drinking Water Report" showed no detection of coliform bacteria in the drinking water system (RWSA 2002). Because human drinking water supply is the primary purpose of the reservoir, vigilance and prevention are essential.

Sources of non-human animal waste in the SFRR Watershed include livestock, land disposal of animal waste, pets, and wildlife. (In some places, Canada geese, which deposit their waste directly in the water, have proven to be a particular problem. It is not known if the geese on SFRR cause such problems, but it is prudent to avoid creating an environment that attracts them.)

Current and potential sources of human waste include septic systems (particularly failing systems), one small wastewater plant, illicit discharges, and, potentially, land disposal of sludge from sewage treatment plants. Studies like the Rivanna Basin Project have shown that fecal coliform concentrations in Rivanna Watershed streams are highest during storm events (RRBR 1998). This fact implies that pathogen pollution is a nonpoint source problem. (Point source pollution concentrations often decline during storms through dilution.) Once in the stream or reservoir system, some pathogens can survive for a long time and some only very briefly (AWWA 1999).

Potentially Hazardous Chemicals

There is no problem with hazardous chemicals in SFRR drinking water. With its large, generally rural character, the SFRR Watershed has a relatively small number of sources of hazardous chemicals. Sampling in the 1970s in the reservoir revealed no serious problems and environmental regulation only has improved since then (Betz Environmental Engineers, Inc. 1977). Sampling of finished water has been ongoing with no problems identified. Almost all VDEQ samples for hazardous chemicals in SFRR tributaries reveal concentrations well below the USEPA's primary drinking water standards even before reservoir settling or water treatment (VDEQ 2000). Finally, many toxins naturally travel bound to sediment which is removed in the water treatment process.

The proposed 29 bypass has raised special concerns regarding catastrophic spills. The bypass would run within a few hundred feet of the reservoir and along an area of steep slopes. A recent study estimated that the bypass could increase the likelihood of a plant shutdown in any given year by between 3.5% and 13.6% depending on the assumptions made (Black & Veatch 2001). Current risk due to existing roadways is estimated to be 2.2% (Figure 9, Black & Veatch 2001).

The background load of stormwater pollutants to the SFRR was recently estimated (based on limited data) as part of the Western Bypass study (Black and Veatch 2001, Table 9). The pollutants come from both natural and human sources, the ratio of which is not known. Human sources include roads, parking lots, developed areas, septic systems, sewage treatment, farming, and more. Overall, significant loads of metals and other pollutants enter the reservoir from natural sources (Table 9). The concentrations of pollutants are estimated to be below EPA limits even before water treatment. The preliminary data suggest that stormwater pollutant concentrations are not currently problematic but vigilance is advisable to minimize increases in loads as development in the watershed continues.

Table 9. Estimated concentrations of metals entering the South Fork Rivanna Reservoir with concentrations in the finished water supply of Charlottesville and urban Albemarle County, VA and EPA standards (Black and Veatch 2001, City of Charlottesville and Albemarle County Service Authority 2000, AWWA 2001).

Pollutant	Estimated Concentration to Reservoir+ (ppm)	Concentration Reported in Drinking Water* (ppm)	EPA Maximum Contaminate Level (MCL) or Action Level (ppm)
Chromium	0.011	<0.01	0.1
Copper	0.011	0.178^	1.3
Lead	0.010	0.00365^	0.015
Mercury	0.0006	<0.0002	0.002
Nickel	0.041	<0.01	0.1

+ These estimates are based on limited data.
* Represents entire urban system, not only SFRR.
^ The value reported is the 90th percentile of all data collected rather than the mean or median.

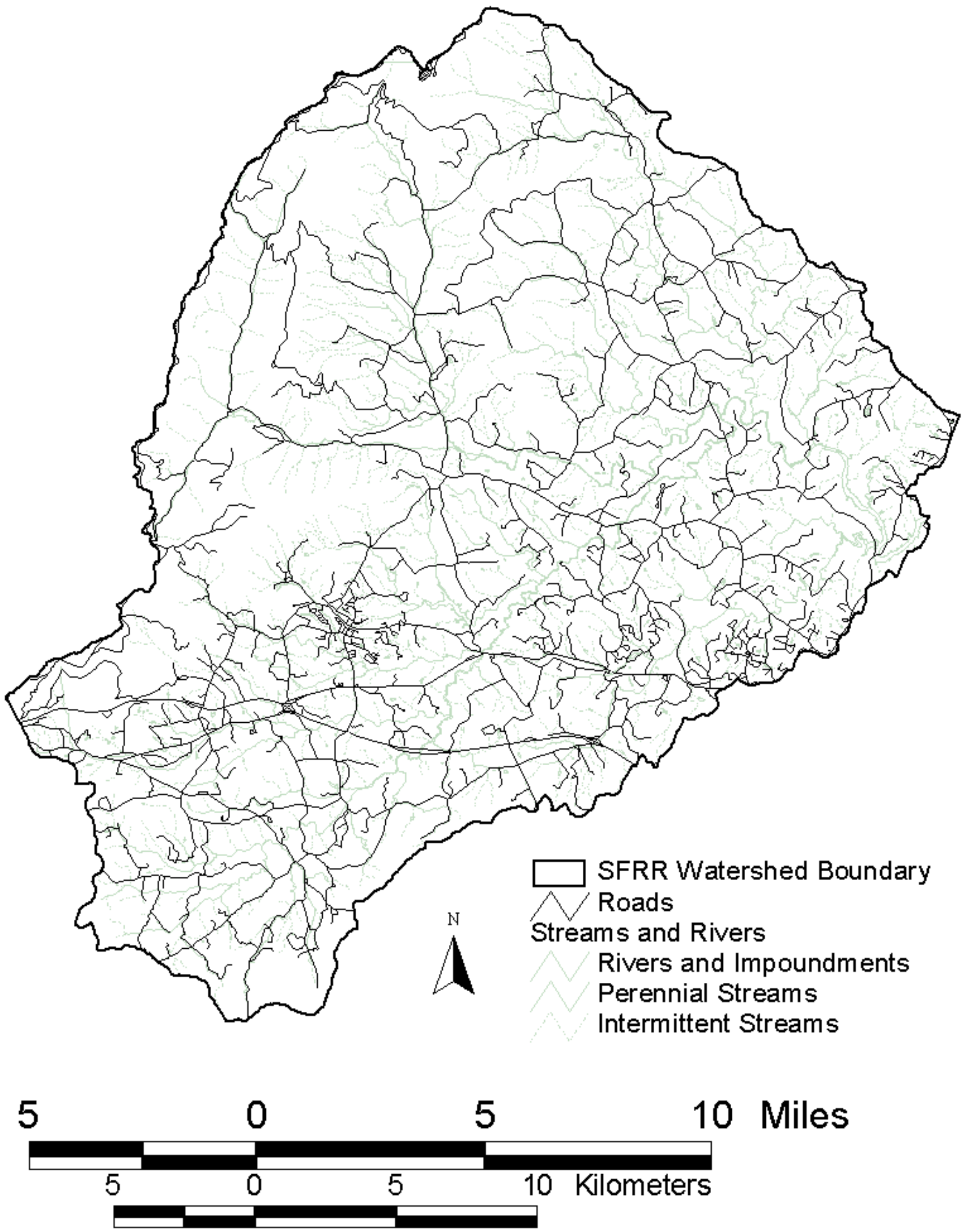


Figure 9. Roads in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA.

There are four known sites of industrial contamination of groundwater in the SFRR Watershed (Figure 10). These include the Greenwood Chemical site (a Superfund site) in the Stockton Creek Sub-Watershed of the Mechums River Watershed, Cooper Industries near the SFRR, Acme Visible Records near Lickinghole Creek, and the Ivy Waste Utilization Center (formerly Ivy Landfill) on Broad Axe Creek. All but Acme Visible Records are pumping the ground water and treating it under agreements with the Virginia Department of Environmental Quality (VDEQ) and/or the USEPA. VDEQ has allowed Acme Visible Records to treat the groundwater in place (VDEQ 1999a). In the summer of 1999, RWSA, Albemarle County, a local developer, and a homeowners association organized to sample water and sediments draining the Acme Visible Records site. Part of the concern was transport of hazardous chemicals toward the SFRR. Concentrations of the chemicals studied appeared to be at or near background levels indicating little reason for immediate concern (ENSAT Corporation 1999). In all of the groundwater contamination cases, monitoring of groundwater is required to assure that hazardous materials do not leave the site in significant concentrations.

The VDEQ has a system for permitting releases of waste from pipes to streams under the requirements of the federal Clean Water Act. The SFRR has a relatively small number of such permits (Figure 10).

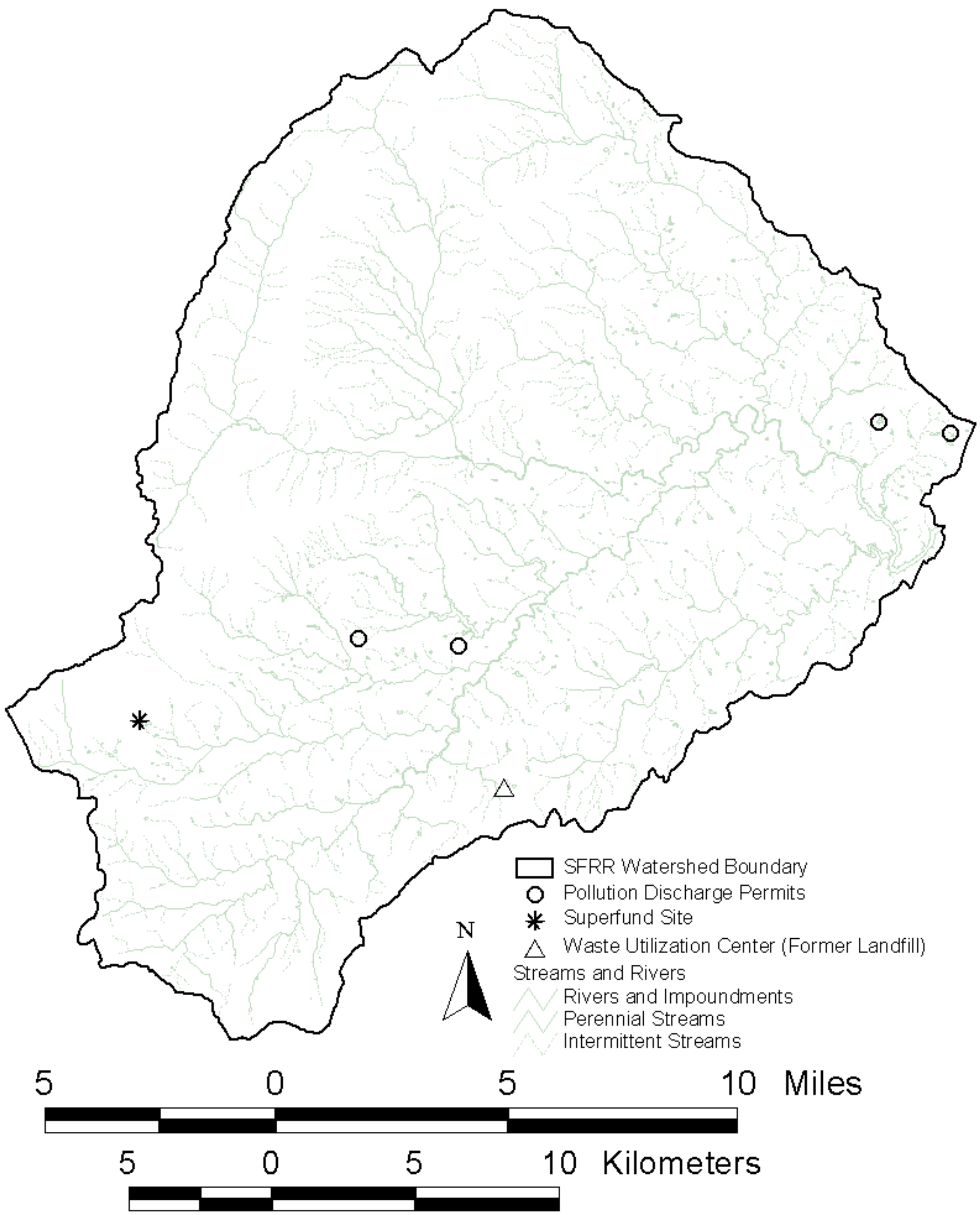


Figure 10. Sites of pollution leaks and permitted discharges in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (VDEQ 1999b).

Residential septic systems can be a source of hazardous chemicals. Of course, it is unwise from the perspective of maintaining a septic system to introduce hazardous chemicals. It is also unwise from a general water quality perspective. Albemarle County requires a Certified Engineer's Report from commercial and industrial facilities (including in-home businesses) with septic systems demonstrating that the groundwater will not be threatened.

A source of potentially hazardous chemicals, which has been recognized only in recent years, is atmospheric deposition. Mercury from coal-burning facilities is a chemical that has become a problem in many areas via atmospheric deposition as well as from natural sources (AWWA 2001). Also, acidic conditions can lead to increased leaching of metals from soils. Little is known about atmospheric deposition in the SFRR Watershed. Acid rain is a major concern in the Shenandoah National Park and nearby areas. Currently, concentrations of mercury and other metals entering SFRR as raw water appear to be below EPA limits for treated water (Table 9).

Arsenic is not an issue in the SFRR. Samples from the SFRR have tested below the limit of detection for arsenic which is 0.002 ppm (Wilson 2000). Arsenic has been detected in at least one Albemarle County stream (Redbud Creek) outside the SFRR Watershed (Hirschman 2000). Arsenic is a product of certain geologic conditions or a byproduct of specific industries. Arsenic also is found in pressure treated wood. Though such wood is ubiquitous, it is a very small source in a large watershed. However, it is worth considering, particularly as it regards construction of structures in and around the reservoir.

Dry Times/Wet Times

Of course, from a water supply perspective a drought is the greatest worry of all. However, ecologically the impacts of dry versus wet weather are quite complex. Each exacerbates and alleviates various problems. In addition to leading to quantity of supply problems, dry conditions and the resulting low flows in the reservoir lead to long residence times in the reservoir and increased stratification. Long residence times allow algae populations to grow and the surface water to heat up. Lack of mixing leads to low dissolve oxygen in deep water and resuspension (via chemical reduction) of metals that cause taste problems and of nutrients that feed algae. On the other hand, high flows carry high loads of sediment to the reservoir and are associated with higher concentrations of fecal coliform bacteria not to mention flooding (RRBR 1998). The weather extremes at both ends of the spectrum can be problematic.

Ecosystem Resilience

Ecosystems, including watersheds, have natural characteristics that confer a degree of protection to the ecosystem and those who rely on it. These protective characteristics sometimes are referred to as "resilience" (Horton and Eichbaum 1991). As long as the protective characteristics are preserved, the natural ecosystem is somewhat resilient to natural disturbances, such as hurricanes and forest fires, and human caused disturbances, such as pollution and development. In this way, the ecosystem's natural resilience provides a service to the human community by protecting the resources people rely on from the ecosystem, such as clean water or fertile soil. If those protective characteristics are destroyed, resilience is reduced, and the ecosystem becomes much more “brittle” or susceptible to problems.

The most important and obvious source of resilience in the SFRR Watershed ecosystem is natural forest. The leaves of the forest intercept rainwater dissipating its energy so that it doesn’t dislodge soil upon impact and cause erosion. The fallen leaves and branches and root systems of the trees slow and trap water that might otherwise run along the surface of the ground and cause erosion. These factors that slow water down tend to encourage more water to soak into the ground. Much of that groundwater will become stream flow at a later time essentially adding storage capacity to the watershed that supplements the limited storage in the reservoir. By contrast, without forest, water runs off the land quickly. Since the reservoir is usually full, this water passes over the dam and is lost as potential storage. Also, the runoff translates into high stream flows that can encourage pollution, stream bank erosion, and flooding. Growing plants in the forest take up nutrients from the water that otherwise could enter a waterway as pollution. The organic material of the forest floor binds and traps nutrients and chemicals. The forest ecosystem may process these materials or sequester them long enough to reduce the impacts to the reservoir. In short, forests produce the cleanest and most reliable flow of water possible.

Fortunately, the SFRR Watershed is estimated to be as much as 73% forested (Figure 11, USEPA 1992). Most of this forest is relatively young. Much of the area was deforested into the early part of the 20th century. Much of the forest is logged commercially with a range of practices ranging from clear cuts to selective harvest. Poor forestry practices can lead to erosion problems and can remove the water quality benefit of the forest for years. Other forestry practices may interfere little with the water quality benefit of the forest.

A special case of the benefit of forests is the waterway buffer (Figure 12, Wenger 1999, USEPA 1995). Forests along waterways provide all the same benefits as other forests, but because of their proximity to the water body, their importance is magnified. They can be seen as filters paralleling the waterways. The width of waterway buffers depends on the management goals Wenger 1999, USEPA 1995). An argument can be made for including entire floodplains in buffers (Figure 12). By nature, floodplains are made of previously deposited sediments which are loose and subject to erosion. Also, because they are subject to flooding, the floodplains have a more intimate connection to the waterways than most of the surrounding landscape.

In some cases, floodplain or waterway vegetation can help stabilize the shoreline and reduce erosion. The bulk of waterway buffer potential occurs along streams. Some stream reaches are well buffered while others are mowed, grazed, or farmed right to the stream edge. Waterway buffers are also an issue along ponds and reservoirs. Waterway buffers are critical to aquatic organisms. They shade the water, keeping it cool. Leaves and branches falling in the stream provide habitat and food for the animals. Waterway forests may be the most critical forests in the watershed. However, waterway forests can’t make up for a heavily impacted watershed.

Buffers along the SFRR itself are particularly important. Anything that passes through unbuffered land along the reservoir goes straight into the drinking water supply. Shoreline erosion on the banks of the SFRR immediately becomes lost reservoir capacity. The homes along the reservoir are served by individual septic systems. The forests between the septic fields and the reservoir provide an added level of protection. It is a great benefit that most of the reservoir shore is forested.

Another example of ecosystem resilience is a healthy stream system. Physically a healthy stream system is in some degree of equilibrium. It will change over time, but it is not subject to severe erosion. A physically healthy stream system floods its floodplain in reasonably common storms (five or ten year or even smaller storms). When the water level reaches the floodplain, much of the energy of the water is dissipated as the water wends its way through the floodplain vegetation. As the water slows down it will deposit sediment in the floodplain, at least temporarily storing some of the sediment load. The fact that the water reaches the floodplain and dissipates energy limits stream bank erosion.

In terms of physical stream quality, the SFRR Watershed probably is lacking in resilience. Many stream channels have become deeply incised from channel erosion over the past few decades or centuries. The streams rarely flood the floodplains that they once inundated frequently. Thus the floodplains are no longer available to the streams to provide resilience to storm effects.

A biologically healthy stream may process the materials coming off the landscape more efficiently than an unhealthy stream. A healthy community of stream and floodplain plants and animals is adapted to capturing, using, and breaking down the materials that the stream carries. Thus these materials are less likely to cause problems in the reservoir. In one example, nitrogen export from watersheds appeared to be controlled by headwater streams (Peterson et. al. 2001). The link between stream health and reservoir health is hard to define but extremely important.

Wetlands are often listed as a major component of watershed resilience. Wetlands are quite rare in Albemarle County relative to counties to the east (Figure 11). The benefits of floodplain wetlands have been described above. These may be the most important wetlands from a source water protection perspective. The emergent wetlands in the reservoir and (and occasionally in its tributaries) may provide some water quality benefits by sequestering nutrients during the growing season (keeping them from the algae). Though rare, groundwater fed wetlands may provide some nutrient processing in the watershed.

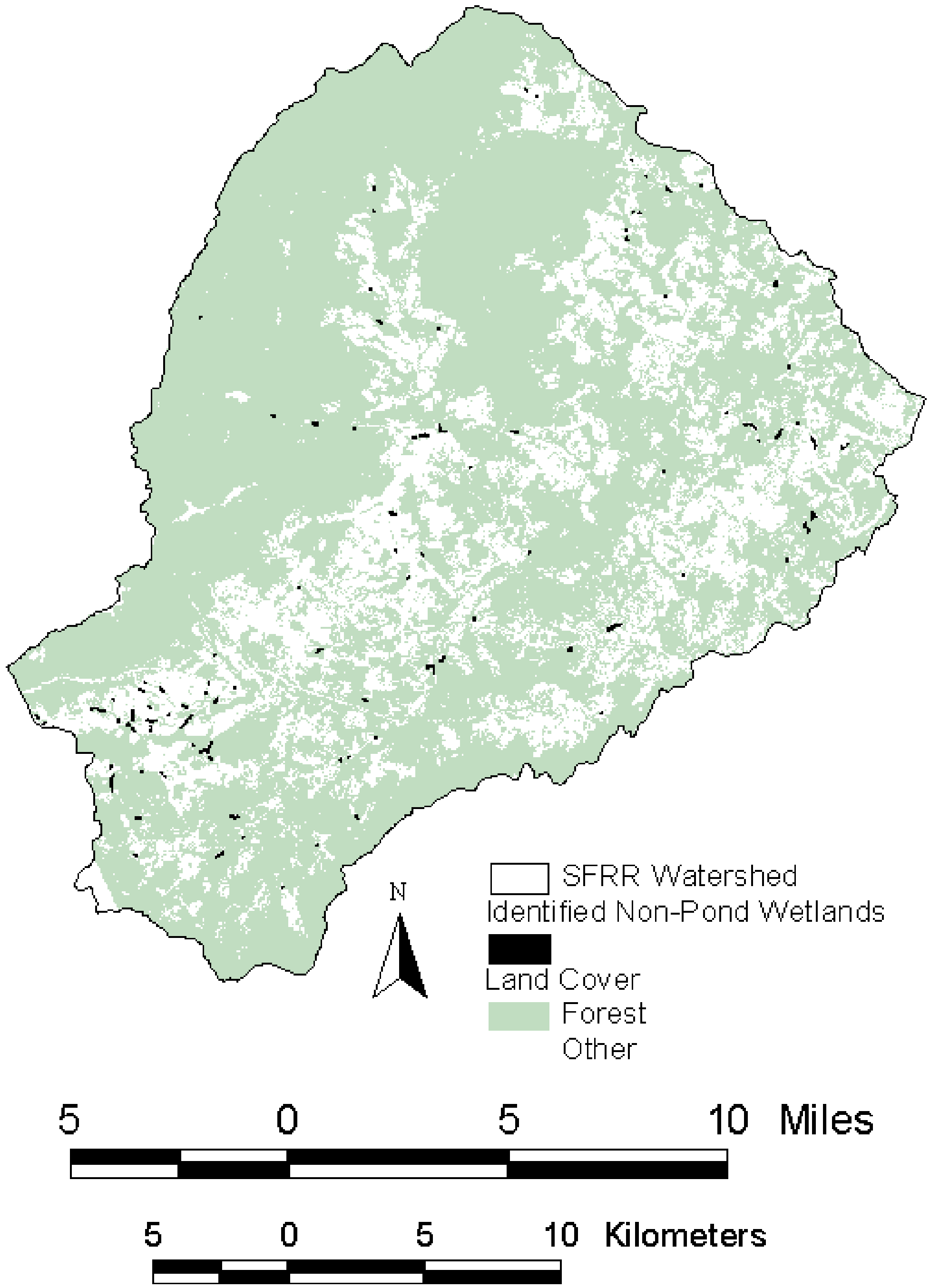


Figure 11. Forests and identified, non-impoundment wetlands mapped to date by the federal government in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (USEPA 1992, USDOI 1988).

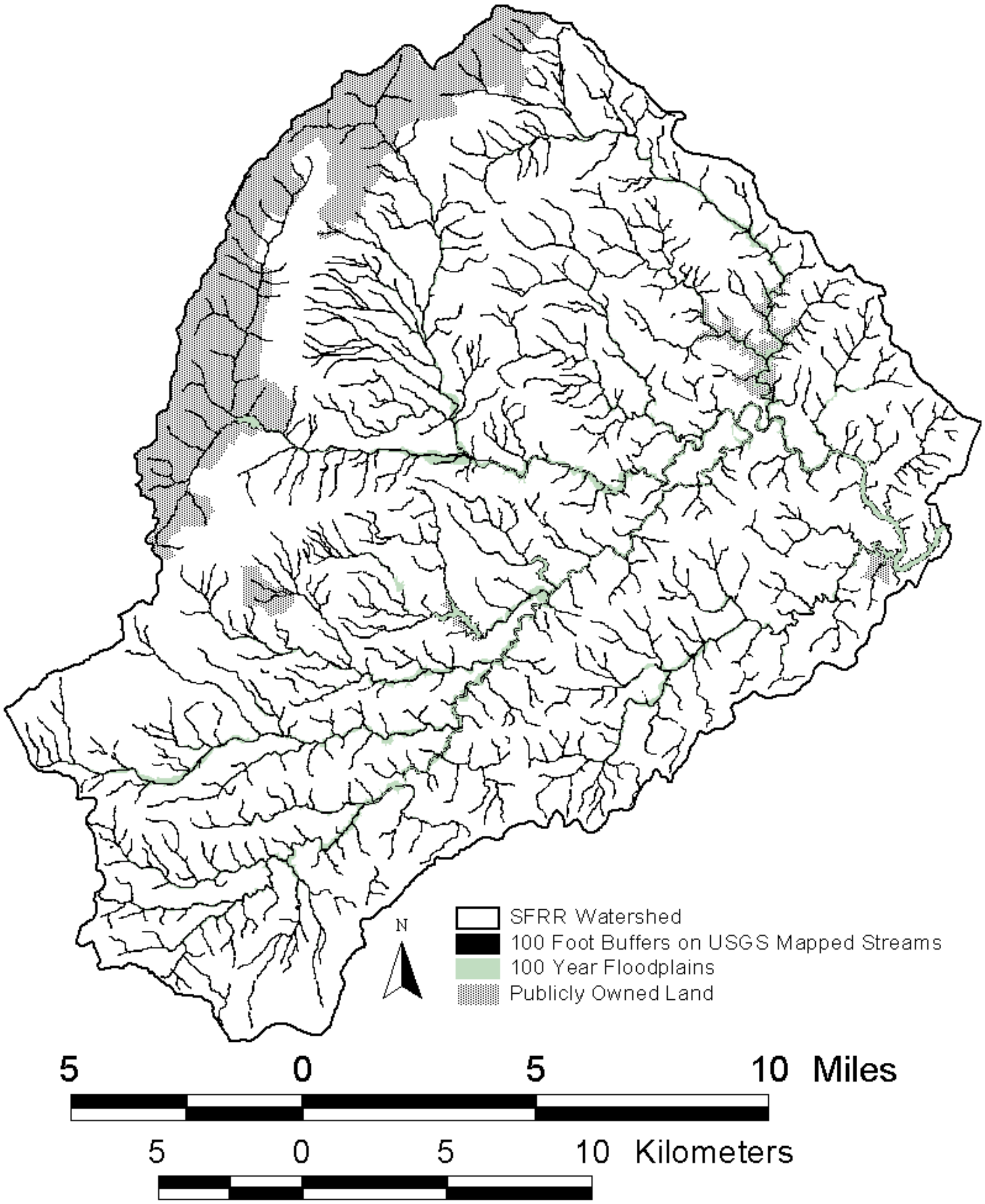


Figure 12. Map showing the extent of 100 foot buffers on streams shown on U.S. Geological Survey maps, 100 year floodplains shown on Federal Emergency Management Agency maps, and public land where buffer protection presumably exists (FEMA 1980). The streams themselves are not shown.

Conclusion

The SFRR has a very large watershed relative to the size of the water body resulting in relatively consistent water supply, large pollutant loads, and management challenges. It is a complex ecosystem with several key variables to understand and address through monitoring and management (Figure 13). Many of the problems with SFRR relate to the same thing that makes it a useful water supply- the increased water residence time relative to the natural river. SFRR has characteristics of a river and a lake. The watershed falls almost entirely in the County of Albemarle and the reservoir is owned by the City of Charlottesville putting responsibility for its care in the hands of the local governments and utilities. As of the early 1990s, the watershed was 73% forested (the best land use for water quality and quantity protection). However, much of the watershed alteration that threatens water quality, as reflected by increased impervious surface, appears to have occurred along the tributaries closest to the reservoir.

A major issue is sedimentation which fills the reservoir at a rate of 0.93% of original volume annually. Sedimentation is a natural process accelerated by human activities. The sources of accelerated sedimentation are poorly understood. Over-enrichment (eutrophication), another human acceleration of a natural process, is an additional problem in the reservoir. Eutrophication is not extreme (as it probably was in the 1970s) but is important to keep at a minimum. Pathogens and potentially hazardous chemicals do not cause problems for water treatment but always require vigilance. Weather conditions at both extremes from dry to wet exacerbate reservoir problems. The watershed as an ecosystem has characteristics that provide natural water quality protection or resilience. These features need to be protected and enhanced wherever possible. They include the forests (particularly the streamside forests), wetlands, and the stream network.

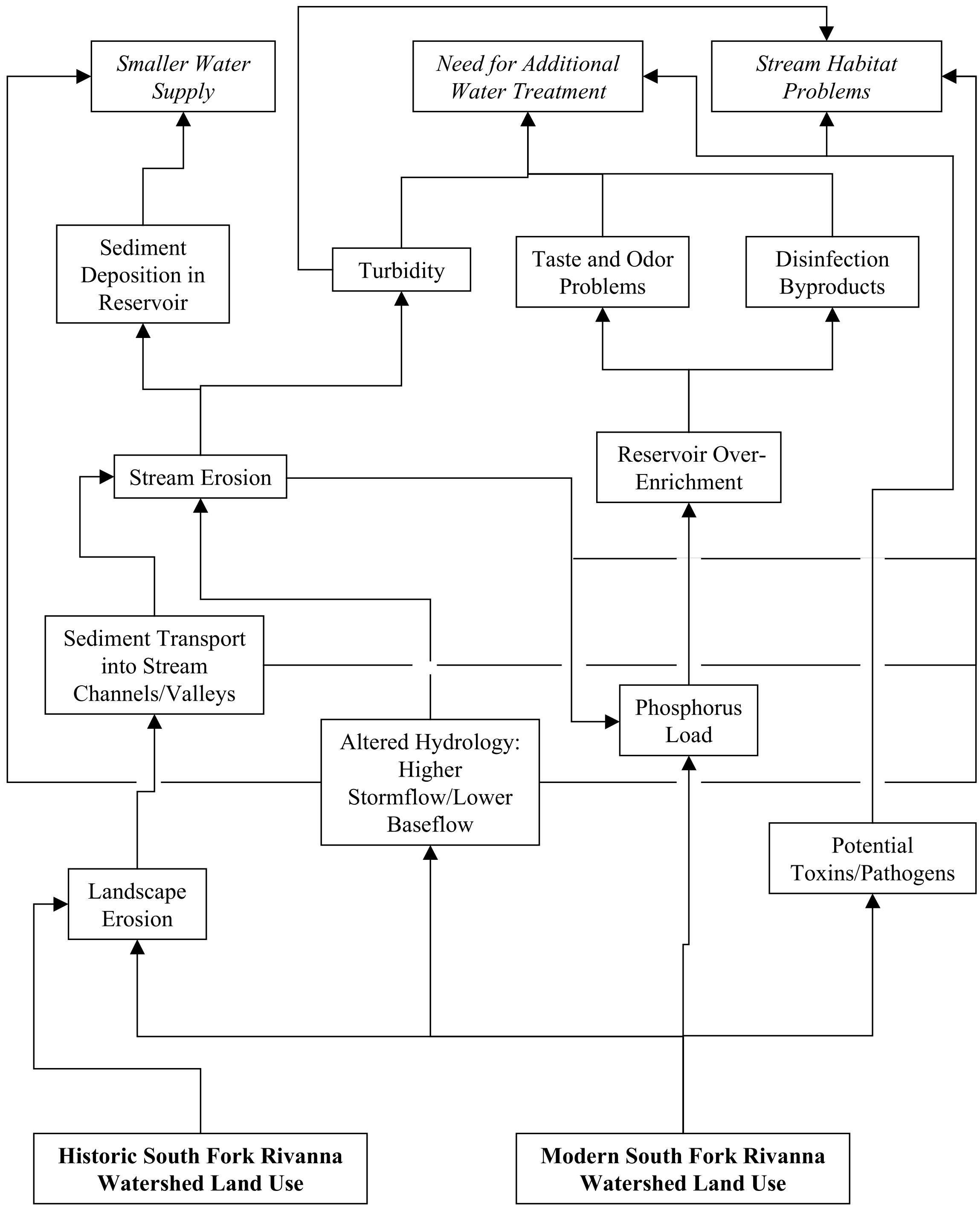


Figure 13. A proposed conceptual model of the interaction of key variables discussed in this report on the South Fork Rivanna Reservoir and Watershed near Charlottesville, VA.

WATERSHED MANAGEMENT HISTORY AND ISSUES

Introduction

Understanding the history of watershed management for the SFRR is essential to updating old strategies and developing new ones. The basic ecological principals that come with the reservoir can't be changed. However, the community has made a great deal of effort to deal with the cultural factors that can lead to water quality problems. These efforts are described in the next section. Also in this chapter, several new and old management issues are highlighted. It would be valuable to discuss these items in developing a new watershed management strategy.

Management History

(Modified from Humphris and Hirschman 1999)

The South Fork Rivanna Reservoir was completed and put in service in August 1966. The reservoir was constructed by the City of Charlottesville in response to water demand in the urban area that was increasing beyond the capacity of the existing Sugar Hollow/Ragged Mountain system. The land, including land surrounding the reservoir to an elevation approximately five feet above the pool, still is owned by the City today.

Surface water supply protection has been a special concern in Albemarle County and the City of Charlottesville since 1972 when the City and County adopted a joint resolution forming the Rivanna Water and Sewer Authority (Table 10). In November 1973, the RWSA appointed an advisory committee to study the reservoir pollution problem. In 1975, a study of the South Fork Rivanna Reservoir was undertaken by Betz Environmental Engineers, Inc. for the RWSA. This study recommended the implementation of a comprehensive watershed management plan that included reservoir management, water treatment modifications, point and non-point source controls, and routine watershed monitoring.

The 1977 report resulting from this initial study, *Water Quality Management Study of the South Rivanna Reservoir and Tributary Area,* by Betz Environmental Engineers, Inc., provided the basic guidelines for future measures taken to provide water supply protection in the area. The first step toward implementing the recommended watershed plan was taken by the Albemarle County Board of Supervisors in September 1977 when they adopted a Runoff Control Ordinance applicable in all water supply impoundment watersheds. The purpose of this ordinance was to protect against and minimize the pollution and eutrophication of the public drinking water supply impoundments resulting from land development in the watershed areas.

In July 1977, a *Report on Alternative Water Supply Sources* prepared by Camp, Dresser & McKee, Inc. was completed. It concluded that the only viable alternatives were: (1) expansion of the South Fork Rivanna Reservoir by the addition of flashboards; (2) development of the Buck Mountain system as a supplement to the South Fork Rivanna Reservoir; and, (3) development of the James River and abandonment of the South Fork Rivanna Reservoir. This study reemphasized the importance of protecting the South Fork Rivanna Watershed.

In 1978, the Board of Supervisors rezoned all publicly owned properties except school sites within water supply watersheds to a conservation district designation.

In August 1979, a second study was completed. The *South Rivanna Reservoir Watershed Management Plan* was prepared by F.X. Browne and Associates, Inc. and the Watershed Management Plan Committee, made up of representatives of agencies and interest groups involved with water supply in Albemarle and Charlottesville. The report recommended: (1) creating the position of a Watershed Management Official, (2) eliminating major point source discharge, (3) that the Virginia Department of Transportation install and maintain erosion and sedimentation control measures as specified in its manual, and, (4) integrating watershed management goals into agricultural, technical, and financial assistance programs.

After 1979, significant efforts were begun to deal with watershed pollution problems. A $5.8 million sewer interceptor was constructed from the town of Crozet to the Moore's Creek Wastewater Treatment Plant (completed in 1988). This allowed for collection of sewage in Crozet through a public system, eliminating several major point discharges and failing septic systems. A $5 million sewage collection system was completed in Crozet. To reduce non-point discharge from the Crozet Community, the Lickinghole Creek Sedimentation Basin was completed in 1994.

In 1980, Land Use Plan amendments to the 1977 Comprehensive Plan were adopted which removed all land from the Urban Area also located in the South Fork Rivanna Watershed.

In August 1980, a moratorium on development was enacted for the proposed Buck Mountain Creek Impoundment Watershed. It remained in place until agreement was reached between the City and County regarding the extent of land necessary to be purchased for the potential future impoundment and the means of financing the purchases.

In December 1980, a comprehensive rezoning of the County placed major limitations on development in the Rural Areas. Special use permit criteria addressed proposed developments located within water supply watersheds. A 1982 revision to the Plan removed watershed properties from Growth Areas in Crozet, Scottsville, Earlysville, and Ivy. These properties, containing over 1,000 acres, were rezoned to Rural Areas the following year. Crozet and Ivy, both located entirely in water supply watersheds, were scaled back in size. In Crozet, the Growth Area was planned to drain into the Lickinghole Creek Sedimentation Basin.

In 1982, a *Section 208 Watershed Management Study of the South Rivanna Reservoir* was completed by F.X. Browne and Associates, Inc. The study concluded that the watershed plan developed in 1977 and refined in 1979 was still valid and should be fully implemented.

A *Report on the James River* prepared by the Rivanna Water and Sewer Authority in 1982 updated the 1977 study of alternative water supply sources. It concluded that the quantity of water in the James River was more than adequate, but the cost of supplying the City of Charlottesville with water from the James River was over $20 million (1982 dollars) greater than the Buck Mountain Reservoir alternative.

A Phase II EPA Clean Lakes project was federally funded to implement agricultural and highway Best Management Practices projects in a portion of the South Fork Rivanna Watershed. The final report*, Phase II Report South Rivanna Restoration Project*, was completed by F.X. Browne in April 1993. The report recommended further monitoring on the South Fork Rivanna Reservoir and new monitoring of the new

Lickinghole Creek facility. The report also reiterated the validity of the Section 208 Watershed Management Study. The Lickinghole Creek monitoring study, *Evaluation of the Lickinghole Creek Detention Basin*, was completed in July 1999. Phosphorus removal was estimated as 37 to 46% (relative to a design target of 45%) and sediment removal was estimated as 37 to 47% (relative to a design target of 90%). These values translated into removal of 2 to 2.5% of the phosphorus and sediment load to the SFRR.

In November 1994, Black & Veatch prepared the *Urban Raw Water Management Plan* for RWSA to provide and update information for planning, permitting, and implementing additional raw water supplies to the year 2040. Three memoranda were prepared regarding the "Buck Mountain Reservoir Evaluation Update," "South Rivanna Bathymetric Study," and the "Feasibility of Flashboards on the South Rivanna Dam."

The plan reported that the RWSA's projected average daily demand in the year 2040 for the urban area would be 18.7 million gallons per day (mgd). Current sources were capable of supplying only 10.1 mgd in year 2040 to satisfy the average daily demands. A deficit of 8.6 mgd was anticipated by year 2040. Additional supplies would need to be on-line by year 2015 to meet the average daily demands of the Charlottesville Urban Services Area.

In 1997 the Rivanna Water and Sewer Authority (RWSA) retained the firm of Vanasse Hangen Brustlin, Inc. (VHB) to assist with the task of future water supply permitting. VHB produced a water-needs analysis for the urban system consisting of a *Demand Analysis* report and a *Supply Analysis* report. These reports updated the figures provided in the Black & Veatch study. According to the reports, water demand in the year 2050 was projected to be between 18 and 21 mgd. Current safe yield (the amount of water the system could supply during a drought of historic record) was between 11.9 and 12.6 mgd, and was expected to decrease to between 4.5 and 4.8 mgd by the year 2050. The safe yield for SFRR alone, estimated as 7.2 mgd in 1997, was predicted to decline to 0 mgd by 2050.

Based on data provided in these reports, additional supplies would be needed as soon as the year 2003 or 2004 if the area were to experience a drought similar to the drought of record used in the analyses. The permitting process must identify and evaluate all realistic opportunities for reducing water demand and/or increasing supply. Ultimately, the least environmentally damaging practicable alternative or set of alternatives must be identified. Almost all of the viable scenarios involved continued use of the SFRR. Protection of the SFRR Watershed would be important for years to come.

Albemarle County updated and combined its erosion and sediment control, stream buffer, and stormwater ordinances into the *Water Protection Ordinance* (WPO) in 1998. The stormwater calculation method was changed from one based on the Universal Soil Loss Equation (USLE) to one based on phosphorus load reductions. The ordinance revision process, which involved the input of a stakeholder focus group, built on the tradition of applying regulations in a way that applied the greatest protections to the drinking watersheds. Stream buffers were applied to a larger number of streams in these watersheds and the phosphorus removal requirements were higher.

Table 10. Timeline of South Fork Rivanna Reservoir (SFRR) and Watershed history and management.

1962	• SFRR land purchased by City of Charlottesville.
1966	• Reservoir filled and water production begins.
1968	• First Albemarle Zoning Ordinance allows high density near SFRR.
1969	• Four fish kills in the reservoir, probably due to low dissolved oxygen at night • Major flood in region.
1970	• Reservoir closed for two weeks after fish kill attributed to Endrin discharge at Crown Orchards.
1972	• Fish kill in Lickinghole Creek attributed to ammonia spill at Morton Frozen Foods. • Rivanna Water and Sewer Authority (RWSA) formed. • Clean Water Act creates National Pollution Discharge Elimination System which primarily requires reductions in discharge of common, point source pollutants.
1973	• RWSA forms advisory committee on reservoir pollution.
1974	• City asks Albemarle to lower zoning density near SFRR. • UVA says SFRR is sick.
1975	• EPA concludes that "accelerated pollution" is occurring, suggests point source interceptor. • Albemarle adopts first "Soil Erosion and Sedimentation Ordinance." • State Water Control Board (SWCB) and Virginia Department of Health (VDH) urge protecting quality of SFRR. • Temporary moratorium on intensive development leads to “Interim Guidelines.” • First reservoir study, funded by Albemarle County, begins under Betz Environmental Engineers, Inc.
1976	• Albemarle Supervisors begin process of “down-zoning” SFRR Watershed. • Nature Conservancy, City, County, and VA Commission on Outdoor Recreation protect 80 acres along SFRR as the Ivy Creek Natural Area.
1977	• Betz study recommends comprehensive watershed management, rigid controls on development in entire watershed, and routine monitoring. • Albemarle Supervisors adopt “Runoff Control Ordinance” for water supply watersheds to attempt to control phosphorus and sediment pollution. • Camp, Dresser & McKee, Inc. study points to expansion of SFRR, a reservoir on Buck Mt. Creek, and the James as possible future water sources. • Clean Water Act amendments tighten restrictions on discharge of toxins.
1978	• Albemarle rezones public properties (other than schools) in SFRR Watershed to a conservation designation.
1979	• Second SFRR study, funded by EPA and carried out by F.X. Browne & Associates, Inc., recommends comprehensive land use control in watershed, reservoir aeration, agricultural grass waterways, and residential sedimentation ponds. • Watershed Management Plan developed by a County/City/regional committee. • Position of Watershed Management Official created (now Watershed Manager).
1980	• Albemarle Supervisors finalize massive down-zoning of Rural areas including SFRR Watershed. • Down-zoning appealed to Virginia Supreme Court- Albemarle prevails. • Moratorium on development in Buck Mt. Creek Watershed enacted.
1981	• 81.5 acres added to Ivy Creek Natural Area.
1982	• Third SFRR study (funded by EPA) states that reservoir is still eutrophic and recommends regional sediment ponds, modification of “Runoff Control Ordinance”, and further study. • Further study of water supply alternatives concludes that the James River option

	would cost 20 million dollars more than the Buck Mt. Creek option.
1983	• Land purchased for possible future Buck Mt. Creek Reservoir.
1988	• Crozet interceptor goes on line removing Crozet's residential, commercial, and industrial sewage from the SFRR Watershed. • Hydro-power plant installed at SFRR dam. • Virginia bans phosphates in detergents.
1991	• Albemarle becomes first non-Tidewater locality to adopt provisions of the Chesapeake Bay Preservation Act to protect stream buffers (Water Resource Protection Areas Ordinance).
1993	• Fourth watershed study (funded by EPA) reports that eutrophication is stable. This grant phase also helps fund implementation of 67 agricultural best management practices (BMPs) and various highway runoff projects in the late 1980s and early 1990s. • Lickinghole Basin, a regional stormwater basin serving Crozet completed (funded by Albemarle County and EPA using Clean Lakes Funding).
1994	• Black & Veatch study of water supply future predicts a shortfall of 8.6 million gallons per day of drinking water safe yield by 2040.
1995/1996	• Major floods in region.
1997	• RWSA and the Charlottesville/Albemarle community formally begin studying future water supply and demand. • VHB/Vanasse Hangen Brustlin, Inc. completes raw water supply and demand analyses predicting a shortfall in drinking water safe yield of as much as 17.5 mgd by 2050.
1998	• Albemarle develops a new Water Protection Ordinance combining and improving previously developed erosion and sediment, stormwater, and stream buffer laws.
1999	• Major drought in region.
2000	• VHB releases analysis of more than 30 alternatives for future water supply.
2001	• VHB releases recommendations for water supply solutions. Continued use of SFRR is central to the recommendation. • Voluntary conservation requested in October due to looming drought.
2002	• Severe drought. • Mandatory water restrictions in place in August. • RWSA Board adopts water supply strategy. The SFRR is central to future plans.

Up-and-Coming and Longstanding Issues

Aging Septic Systems

Most residences and businesses in the SFRR Watershed except those in Crozet are served by septic systems. In good working order these systems do a good job removing phosphorus and a good to fair job removing nitrogen and pathogens. They are estimated to have a life of about 30 years if they are well-maintained. They are rarely well-maintained. Many houses in the watersheds were built in the 1950s, 60s, and 70s.

The soils characteristic of Albemarle County generally are considered to be less vulnerable than those of other (sand or limestone) areas to septic system pollution of groundwater and surface water. However, the vulnerability of Albemarle's soils is not well understood. Also, with abundant failures, there could be problems. Failing systems can release nutrients and pathogens into the waterways with little treatment. These failures certainly can be a local (e.g. a homeowner's well can become contaminated) problem. It is unknown whether they can pose any threat on a watershed scale. More research is needed.

Route 29 Western Bypass

The debate about finding a bypass for the 29 North corridor has been ongoing for years. The Virginia Department of Transportation (VDOT) has selected a route (known as the western bypass) that passes within a few hundred feet of the reservoir. While there are other roads that pass near the SFRR (three bridges cross it), this site selection by VDOT is particularly problematic because of the steep slopes down to the reservoir from the proposed road, the proximity to the raw water intake, and the amount and type of traffic expected on the road.

Three issues stand out. First, during construction an increased sediment load to the reservoir could shorten reservoir life by 2.3 to 5 months depending on erosion and sediment control measures applied (Black and Veatch 2001). Second, after construction there will be a small increase in pollution to the reservoir from road runoff. Third, and most troubling, the presence of the road in that location will increase the likelihood of a spill that would force shutdown of the water treatment plant. From one section of the road, a spill could reach the reservoir in three minutes and the water intake in four hours (Black and Veatch Corporation 2001). Estimates are that the annual probability of such a shutdown would be between 2.3% and 9.2% (on top of an existing probability of 2% from roads already present) depending on the assumptions made (Black and Veatch 2001).

Livestock in the Reservoir and its Tributaries

Despite the major efforts that the community has made at significant expense to protect the South Fork Rivanna Reservoir, cows still freely wade its waters in a few places. Waste from cows in the reservoir means direct deposit of pathogens, nutrients, and organic material with no processing by the landscape or tributary ecosystems. It also means erosion on the reservoir shores. Livestock in the reservoir tributaries present a similar, if less direct, problem.

Reservoir Waterfront Development Pressure

Maintaining an undeveloped waterfront on SFRR is an important goal and challenge. Most landowners have maintained or established a forested buffer around the reservoir. However, the attraction to the water is great and the temptation to clear land or install structures near the reservoir is strong for some.

There are several threats to drinking water from waterfront development. These threats include less filtering of runoff, loss of ecological integrity, possible introduction of nutrients and pesticides for lawn maintenance, increased general activity and disturbance by people and pets, increased shoreline erosion, increased populations of Canada Geese, and possible storage of undesirable materials such as gasoline near the reservoir.

If the SFRR were built today, a much larger buffer likely would be purchased. Plans for a possible future Buck Mountain Reservoir include a 300 horizontal foot, publicly owned buffer. The Baltimore City reservoir system has publicly owned buffers of 1000 to 2000 horizontal feet. The public land around SFRR includes roughly five vertical feet (translating into only a few horizontal feet in some cases). More substantial than the protection from the publicly owned land is the buffer protection in Albemarle County's Water Protection Ordinance (WPO). The WPO protects 200 horizontal feet from the edge of the 100-year floodplain from new development. The WPO also contains restrictions on vegetative clearing in the buffer zone. It remains important to use this tool and others to protect and improve the reservoir buffers.

Recreation and the Reservoir

A secondary use of SFRR is recreation. Boating, rowing, and fishing are common recreational uses. Swimming and gasoline engines (except by specific permit) are prohibited. Planning for such recreation is a function of the Albemarle County Department of Parks and Recreation. Howevever, recreation cannot be ignored in a watershed management strategy because of potential impacts.

Dry Conditions in the Moormans River

The Sugar Hollow Reservoir is a major source of drinking water for the Charlottesville/Albemarle area. Presently, the community could not do without this water supply. Water is withdrawn from Sugar Hollow Reservoir and piped to the Ragged Mountain Reservoir/Observatory Water Treatment Plant system. Of course, withdrawal of water for water supply results in less water to the river ecosystem (Figure 14). There currently is no legal requirement to provide for minimum instream flow in the Moormans.

The Moormans, like other streams on the eastern slope of the Blue Ridge, may have dried out at the surface occasionally before the Sugar Hollow dam was built. Now it is dry much more often and for much longer periods including significant stretches of the summer and fall in most years.

The river is valued by many as an ecological, recreational, and cultural resource. It is designated as a Scenic River by the Commonwealth of Virginia and County of Albemarle. There has been a significant amount of citizen pressure applied in an effort to see the issue addressed. Also, there has been some public discussion of integrating the topics of source water, instream flow, water conservation, and drought management.

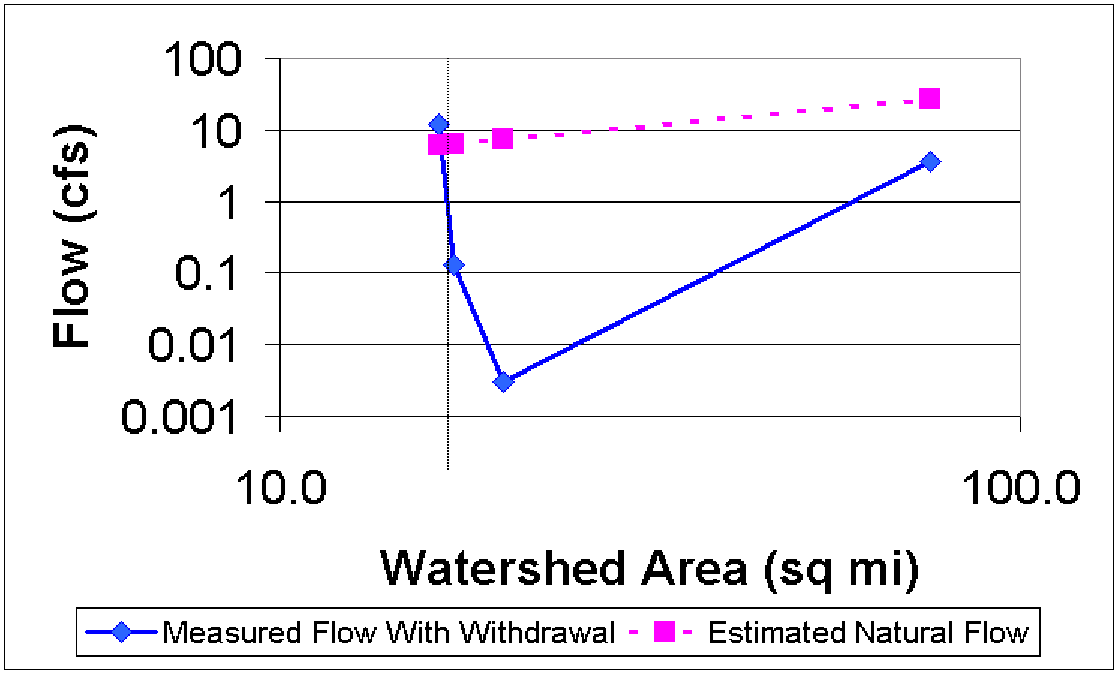


Figure 14. Flow by watershed area for sites on the Moormans River west of Charlottesville, VA on 30 August 2000. Vertical dashed line indicates location of the Sugar Hollow dam. Moving right on the horizontal axis represents moving downstream (Bowler et al 2001).

There are important connections between the Sugar Hollow Reservoir and the SFRR. First, the Moormans Watershed falls within the SFRR Watershed. Second, the distribution systems for the water from the Observatory Water Treatment Plant and South Fork Rivanna Water Treatment Plant are interconnected. Over the past few years RWSA has preferentially used water from SFRR to the extent possible in an attempt to reduce withdrawals from Sugar Hollow and impacts on the Moormans.

In the late summer of 2000, RWSA installed a valve that allowed release of 0.6 cfs (0.4 mgd) of water per day from Sugar Hollow Reservoir to the river. Under certain conditions, this release will do a good deal to improve river flow (Bowler et. al. 2000). The RWSA has made clear that in the case of a significant drought, the release would have to be stopped to protect water supplies. There has been discussion about modifying the release to provide greater benefits to the river ecosystem. The Virginia Department of Game and Inland Fisheries (VDGIF) has proposed varying the release to better mimic natural conditions (Fernald 2000). At the request of Albemarle County, VDGIF will be researching how to get the most out of the release. Any modifications to the release regime will have to be in the context of the importance of the Sugar Hollow Reservoir as a water supply and by agreement of the City, County, and utilities.

South Fork Rivanna Reservoir Tailwater

The quantity of the water released from the SFRR dam (known as the tailwater) is an issue as well. Currently, flows may sometimes be supplemented by the reservoir release. The consultants on the water supply search project have proposed at least temporarily modifying that strategy so that some of the water from the reservoir that sometimes supplements flow can be kept in storage for use as drinking water during dry periods (VHB 2001b).

From an ecological perspective, the quality of the SFRR tailwater may be as large an issue as the quantity. A study by a biology student at Mary Baldwin College (Bond 1999) showed that there may be problems with low oxygen in the water flowing from SFRR. Based on what is known about the water in the SFRR and about reservoirs in general, this finding does not come as a surprise. The reservoir stratifies in the summer with warm water on the top and cool water on the bottom. The warm water is filled with algae. During the day the algae in this upper layer produce more oxygen than they consume keeping the layer oxygenated. At night they consume oxygen and produce none, possibly resulting in low oxygen conditions. If water flows over the dam in the day it should be oxygen-rich while at night it may be oxygen poor. In any event, the water can be quite warm which is harmful to the stream below the dam. Cool water deeper in the reservoir is oxygen-poor. The bacteria on the bottom use oxygen as they consume the dead algae that have dropped from the surface layer. When water is released from the bottom of the reservoir, it is likely to be very oxygen-poor, but reasonably cool. If water is released entirely from the top or entirely from the bottom it is likely to be poor quality from either a temperature or oxygen point of view (or both). It would be desirable to address this issue along with the quantity issue.

Another issue with the tailwater is the impact of intermittently turning on and off the hydropower plant. Operating the plant in such a way results in dramatic changes in downstream flow that could be stressful for the ecosystem (Rice 2000).

Chlorination By-Products

In 2002, USEPA applied stricter standards to chlorination (or disinfection) by-products. Chlorine is used in SFRR drinking water to kill bacteria and other pathogens. It is particularly useful in preventing growth of pathogenic populations as the water travels between the treatment plant and the tap. Use of chlorine provides major health benefits through disease prevention. When chlorine interacts with organic materials, a chemical reaction can occur generating low levels of disinfection by-products. At high levels, the by-products are believed to be carcinogenic. Since the water treatment process removes most organic compounds, disinfection by-products generally are minimal.

There is a link between watershed management and disinfection by-products. Algae use carbon dioxide from the atmosphere to build organic compounds. Organic materials also run off the landscape along with other sediments. A seasonal trend in disinfection by-products seems apparent (Figure 15, Figure 16). For both trihalomethanes and haloacetic acids (two categories of disinfection by-products) concentrations are lower in the fourth and first quarters of the year (October through March) and higher in the second and third quarters (April through September). At present, the mean annual concentrations are well below the standards set by EPA. The more that concentrations of algae and other sources of organic matter can be reduced, the easier it will be to keep concentrations of disinfection by-products low.

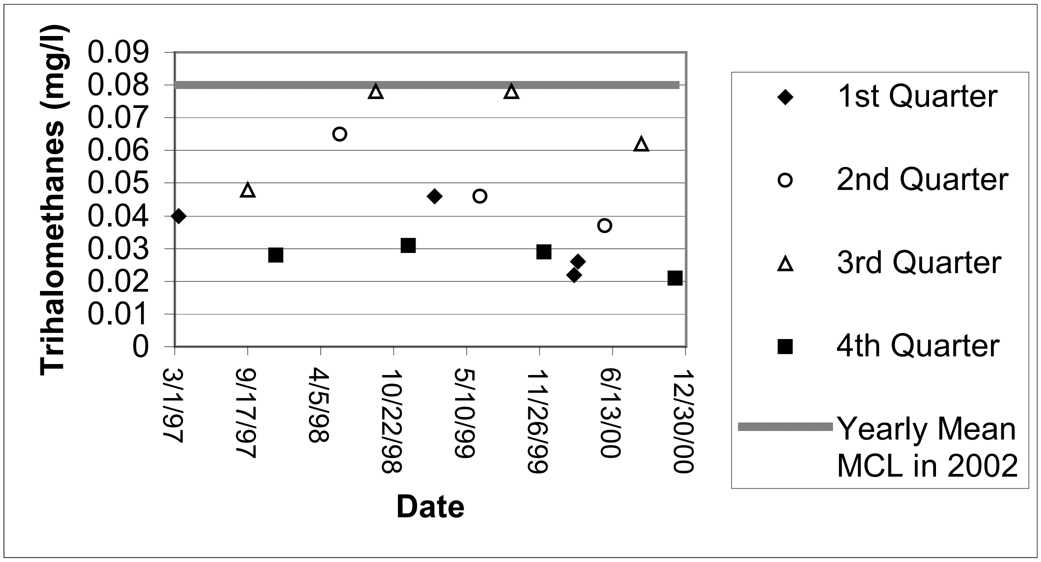


Figure 15. Concentrations of trihalomethanes (a disinfection by-product) in the water leaving the South Rivanna Water Treatment plant (Charlottesville, VA) by time of year.

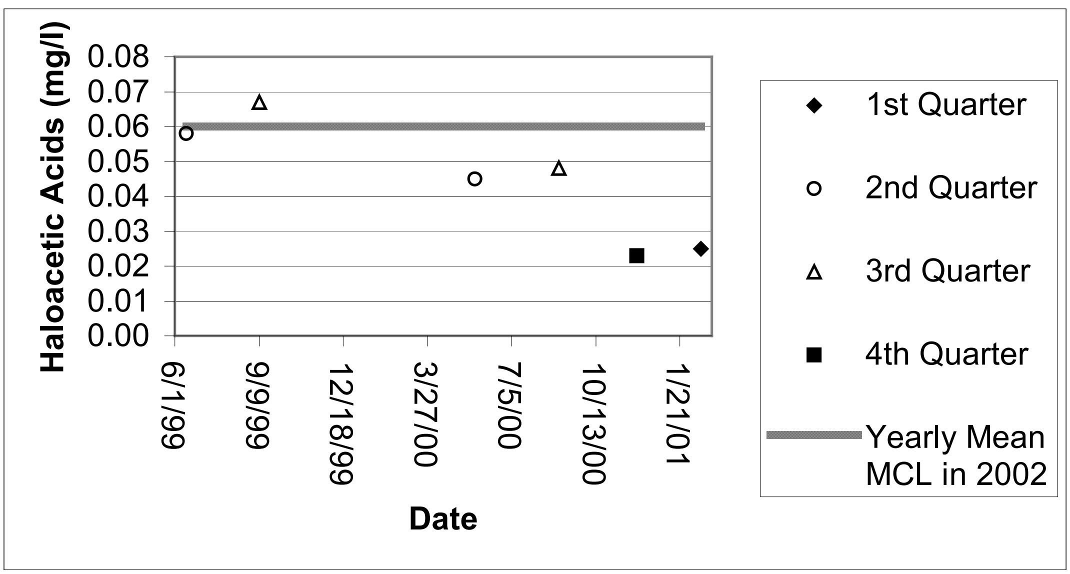


Figure 16. Concentrations of haloacetic acids (a disinfection by-product) in the water leaving the South Rivanna Water Treatment plant (Charlottesville, VA) by time of year. (Note that the data set is quite small.)

Lickinghole Stormwater Basin

The Lickinghole Basin is an impoundment of Lickinghole Creek just below the Community of Crozet. Lickinghole Creek drains the designated development area as well as upstream rural lands. Because of its large watershed, it is really a super-regional basin. It has a much larger watershed than other regional basins in Albemarle County. Lickinghole Basin is the only regional (or super regional) basin in the SFRR Watershed.

In essence, the impoundment was created to intentionally trap pollutants through the same processes that unintentionally trap pollutants in the SFRR. The principle is that impounding the water will slow it down long enough to allow sediment to drop out along with nutrients, metals, etc. Additionally, it is hoped that biological activities in the water column and associated wetlands will process pollutants. The settling and processing in Lickinghole Basin should reduce the impacts of the urban development of the only County-designated development area in the SFRR Watershed, Crozet.

As new construction occurs in the Crozet area, developers pay Albemarle County a pro rata share of the original cost of the basin. Through this fee, the developer fulfills pollutant removal requirements by repaying the County for the pollution removal functions the basin is designed to provide. As a result, many developers are not required to install on-site pollutant removal structures (Best Management Practices or BMPs) as they are required to do in other areas of the County. (Some on-site BMPs are applied to address erosion control requirements and to satisfy proffers for rezoning proposals.)

When it was designed, the Lickinghole Basin represented a state of the art approach to removing pollutants from the urban runoff expected in the Crozet development area. However, it may be time to reconsider the Lickinghole Basin pro rata share policy. During the design stage, much evaluation of regional BMPs versus subregional and on-site BMPs occurred. Since that time, on-site BMPs have evolved to become more efficient than when Lickinghole Basin was designed. Also, when the Basin was being designed and constructed, the Water Protection Ordinance had not been adopted and on-site BMPs were not in widespread use. Today it is common to use on-site BMPs, regional BMPs, or both to minimize water quality degradation, flooding, and channel erosion from watershed development. Analysis of a small set of monitoring data suggests that while Lickinghole Basin may be coming close to its 45% target for phosphorus removal with values in the range of 37% to 46%, it is underperforming its sediment removal design objective (F.X. Browne, Inc. 1999). Lickinghole Basin was designed to remove 90% of incoming sediment. It appears to be removing only 37% to 47% of the sediment load (F.X. Browne, Inc. 1999).

The best protection from Crozet development for the SFRR would be to drop the pro rata share system and require on-site BMPs along with the existing protection from Lickinghole Basin. Albemarle County's stormwater ordinance is based on removing phosphorus. A developer estimates (and County staff review) how much the phosphorus load will increase after the site is developed. The developer is responsible for removing the portion of the post-development phosphorus load that is the result of the development. This amount is usually represented as a percentage and it can be as high as 65% or higher. The County has eight other regional basins besides Lickinghole. For the remainder of the County, there is no pro-rata share system and the developer must remove the phosphorus using on-site BMPs. On-site BMPs are available that, according to general information in the scientific literature, remove as much as 65% of phosphorus (Albemarle County Department of Engineering and Public Works 1999). Since Lickinghole Basin is estimated to provide at best a 46% removal rate, the present situation is one in which less water quality protection may be required from the Crozet development area, which is within the SFRR Watershed, than from other development areas outside the SFRR Watershed. By contrast, requiring on-site BMPs would allow a double layer of protection for SFRR known as a "treatment chain." The County will have to decide whether or not to make protection of SFRR stronger than other waterways by requiring on-site BMPs instead of the pro rata share.

Zebra Mussels

The zebra mussel (*Dreissena polymorpha*) is an exotic species of freshwater mussel that can cause tremendous fouling problems on intake pipes and other structures (Zebra Mussel Information Clearing House). They also can cause general environmental problems including harm to native mussels. They invaded the Great Lakes in the late 1980s. Since that time they have spread dramatically around the United States.

Zebra mussels have recently invaded Northern Virginia, and it is almost inevitable that they will reach Central Virginia (Figure 17, USGS 2000). It may be wise to put measures in place to prevent infestation of SFRR and its watershed and have the knowledge on hand on how to respond if they do arrive. Much of the prevention involves education of those who might bring boats to the area from infested waters.

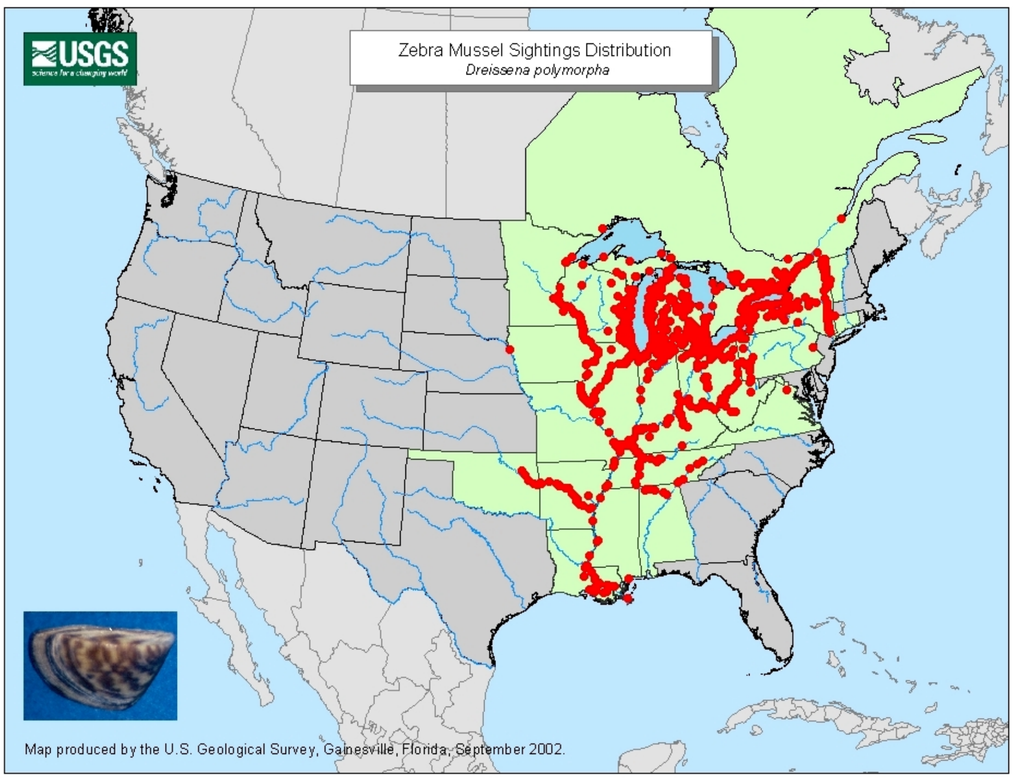


Figure 17. Zebra mussel sitings in the United States (USGS 2002).

James Spinymussel

The James spinymussel (*Pleurobema collina*) is a state and federally listed endangered species. Its strongest populations are found in Albemarle County, some of them in the SFRR Watershed (Figure 18). Fresh water mussels are vulnerable to many of the same problems that do or could effect the drinking water supply- sedimentation, other pollutants, and general ecological decline. Many measures taken to protect the SFRR will also protect the spiny mussels and vice versa.

Biosolids

Disposal of sludge from sewage treatment plants and intensive animal agriculture by spreading on farm fields are two separate, but related, issues. (The Rivanna Solid Waste Authority does not land apply sludge but rather composts the material for sale.) Sewage sludge application is considered by many to be both a good means of disposing of the waste and amending agricultural soil. However, it raises concerns regarding water quality both in terms of nutrients and pathogens. In order to prevent problems, the biosolids industry is regulated by the Virginia Department of Health. Counties cannot prohibit biosolids application but they can apply limited regulation. (Just how much a county can regulate biosolids will be decided in pending court cases.) VDH bases permitted biosolid application rates on the concentration of certain materials in the soil of the site before application in order to avoid over-application. The VDH regulations are based on federal laws enforced by the USEPA.

Application of farm animal waste to the landscape is a longstanding practice with a new twist. Modern agriculture is more intensive than in the past generating more waste that must be disposed of off-site. On the mixed-use farm of the past, there was often enough land to assimilate the waste produced by modest concentration of livestock. Intensive animal agriculture is virtually nonexistent in the SFRR Watershed but is common in the nearby Shenandoah Valley, particularly in the form of chicken houses. Application of animal waste to the landscape has traditionally been limited by the nitrogen concentrations in the receiving soils. There is movement to shift to limitation based on phosphorus concentrations. Because many soils in the Shenandoah Valley are already saturated with phosphorus, farmers could be going farther to dispose of animal waste through land application than in the past. The SFRR Watershed is a possible location for this land application. Concerns would be similar to those raised by the sewage sludge.

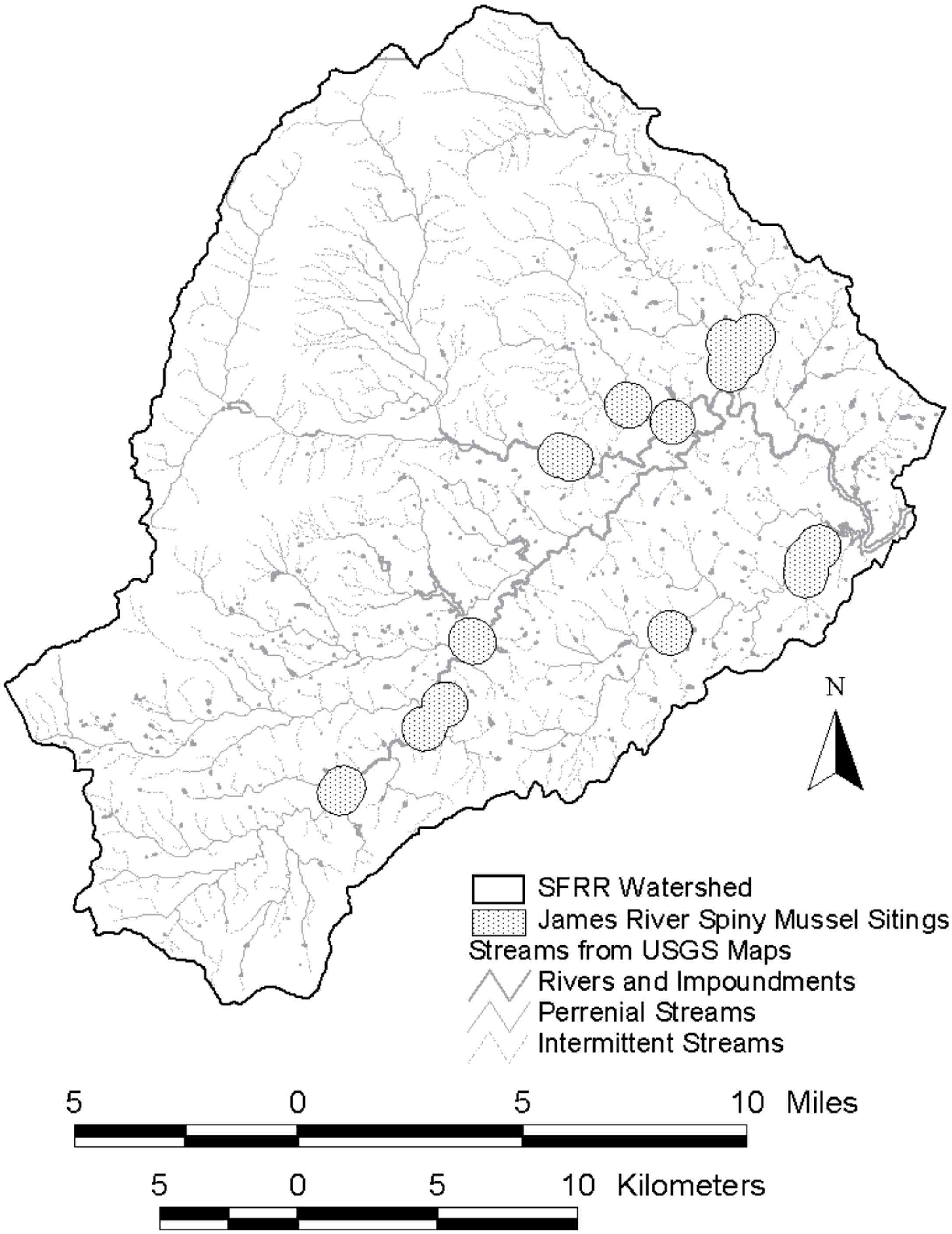


Figure 18. Sitings of the endangered James River spiny mussel in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (VDGIF 2000). Only the approximate location of the sitings is provided.

West Nile Virus

The issue of West Nile virus is not directly related to water quality, but it is related to many of the best management practices used to protect water quality. The vector for West Nile Virus is the mosquito. Structures that hold water are potential mosquito breeding habitats. Those that drain completely or that evolve into ecosystems with predator populations will be less hospitable to mosquitoes. Stormwater and other water quality policies will have to account for the mosquito issue while still protecting water quality.

Conclusion

The local community has done a great deal to protect the SFRR over the years making it a regional leader in watershed protection. Highlights include multiple studies of the reservoir, the 1979 management plan, creation of a full-time staff position, a major down-zoning, and development of ordinances to deal with stormwater, erosion control, and stream buffer protection. There have also been changes at the state and federal level that have benefited the SFRR.

Several specific issues could be addressed in future watershed management efforts. Among these are the impact of septic systems on drinking water, risks associated with the US 29 western bypass, livestock access to the reservoir and its tributaries, and minimizing chlorination by-products (that appear to be related to eutrophication). Strategies might be considered to reduce the impacts of both the Sugar Hollow Dam and the South Fork Rivanna Dam on downstream ecosystems without threatening water supply. County policy regarding the regional Lickinghole Basin may be leading to a lower level of protection from stormwater pollution in Crozet than is afforded in other, non-water supply development areas. The land application of biosolids is another up-and-coming issue.

RESERVOIR AND WATERSHED CHANGES OVER TIME

Introduction

Many changes have occurred in the SFRR and its watershed over the reservoir's history. Enough of the changes were for the better that conditions have improved. Some of these changes were the result of management efforts and some were not. Scientifically it is difficult to assign the changes to specific management measures of other factors. Despite the difficulty, it is essential to explore the changes and do the best possible job making connections. This step is critical to developing a new watershed management plan.

At least three types of data are available to help in understanding the changes that have occurred. Data on subdivision and other land use issues (mainly from the Albemarle County Department of Planning and Community Development) provide a look at the results of efforts to manage land use in the SFRR Watershed. Data from actual water quality monitoring (carried out locally, by consultants, and by VDEQ) along with anecdotal information from water treatment operators provide a look at the results of management in the water. Data from surveys of the bottom of the reservoir shed light on the sedimentation process.

Development in the Watershed

In 1980, the County of Albemarle eliminated most designated growth areas in SFRR Watershed and much of the rest of the County in an effort to protect agriculture and forestry, protect water supplies, limit the need to provide services, and protect natural and cultural resources. Since 1980, the minimum lot size has been 21 acres rather than two acres. However, parcels in existence in 1980 were imbued with five division rights. The owners have the right to subdivide those parcels into as many as five lots as long as each is at least two acres in size. This large number of subdivision rights has translated into steady development of rural land in the SFRR Watershed.

Only the village of Crozet is designated as a development area (Figure 19). (A few areas retain a designation of Village Residential.) Development area zoning in Crozet promotes higher population densities. The development area is served by the Lickinghole Stormwater Basin, which is intended to reduce pollutant loads reaching the reservoir. Other than in the Crozet area, densities are highest in Ivy and near Charlottesville (Figure 19). Much of this area was developed under previous zoning, particularly because of the proximity to the City.

Since 1985 (when consistent record keeping began), the population growth rate in the rural planning areas most closely matching the SFRR Watershed has been between 1.27% and 1.65% and probably closer to the latter (Figure 20 and Figure 21). The average for the rural areas has been 1.49%. The average for the development areas has been 1.94%. In general, new parcels are being created more quickly in the County's water supply protection areas than in rural areas outside the water supply watersheds (Figure 22, Clark 2001).

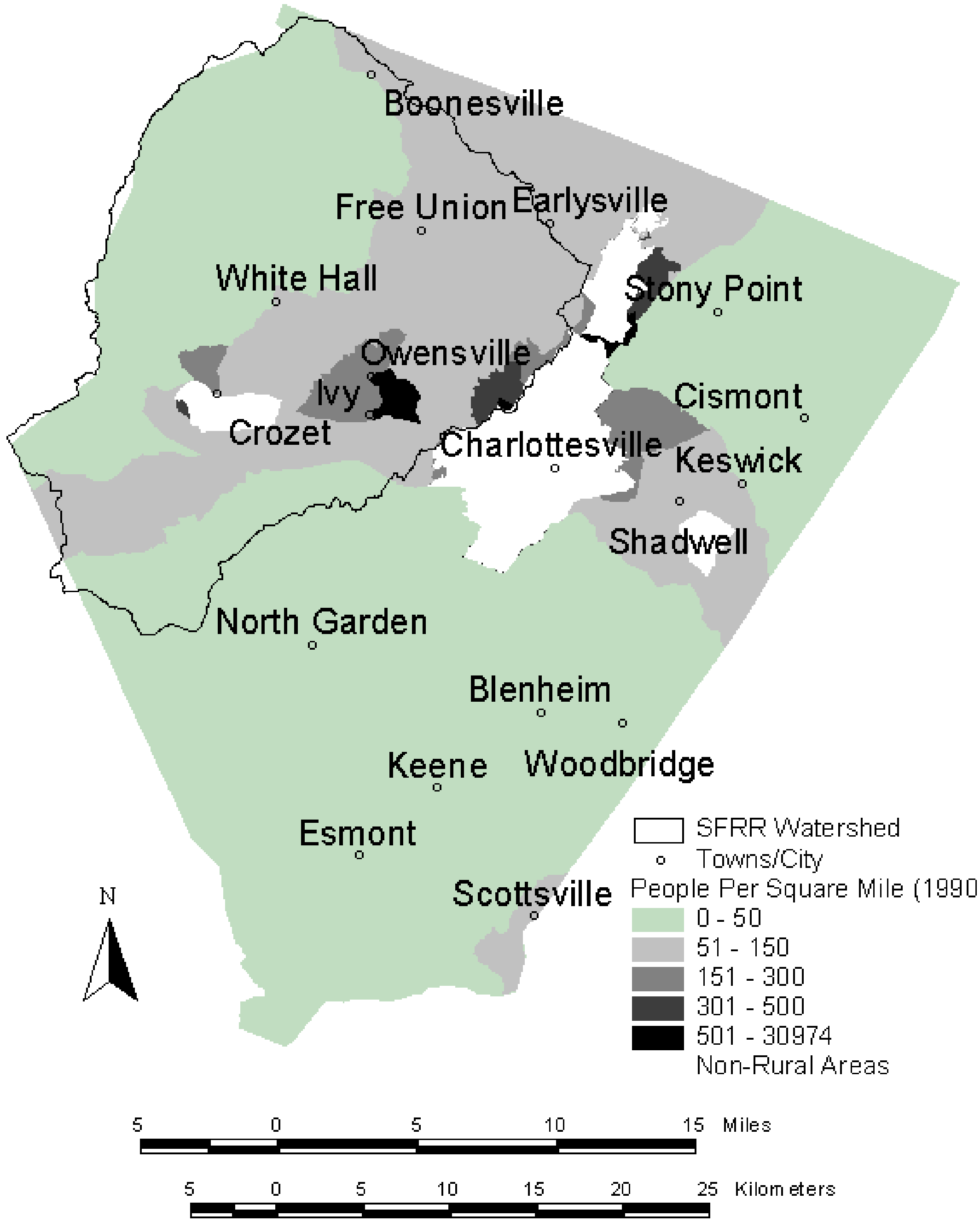


Figure 19. Map showing the Crozet Designated Development area, villages in the South Fork Rivanna Watershed (near Charlottesville, VA), and 1990 population densities in the watershed (US Department of Commerce1990).

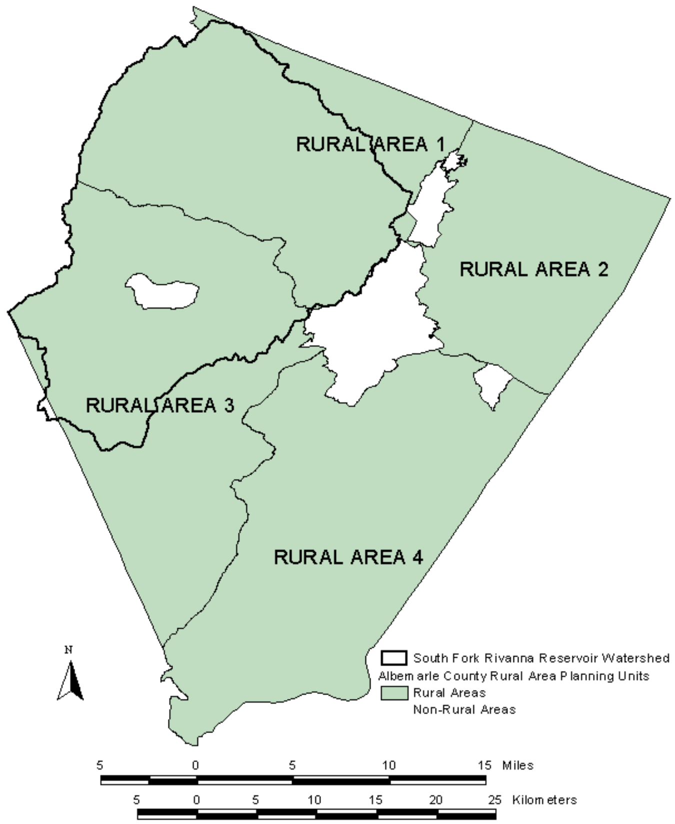


Figure 20. Albemarle County, VA Rural Planning Units and the South Fork Rivanna Reservoir Watershed.

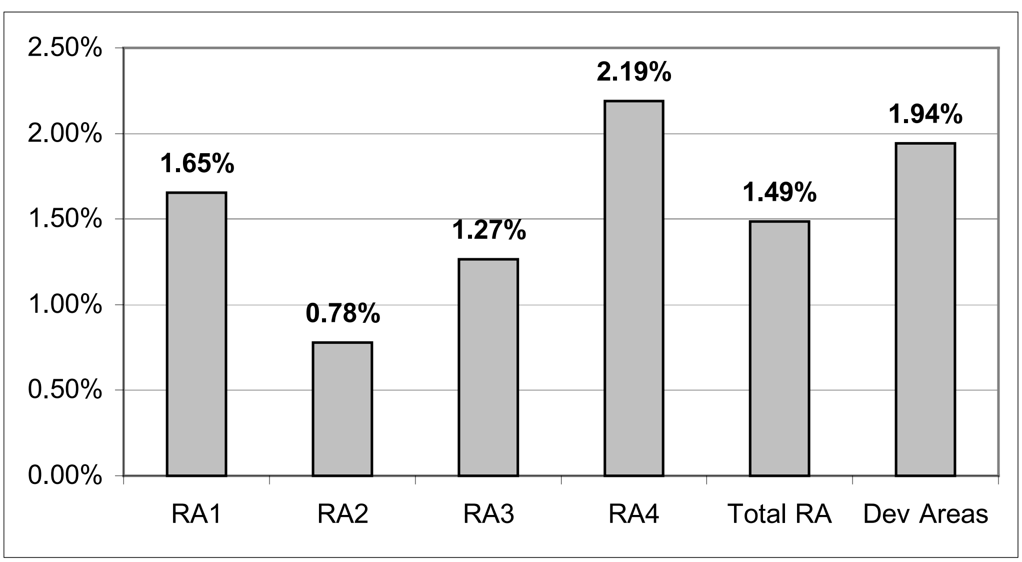


Figure 21. Population growth rates by rural planning area (RA) and for the development areas of Albemarle County, VA (1985-2000). RA1 roughly corresponds with the South Fork Rivanna Reservoir Watershed.

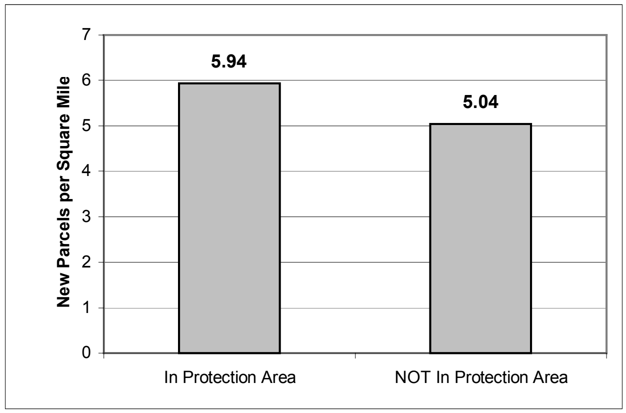


Figure 22. Estimated number of new rural area parcels per square mile between 1985 and 1999 inside and outside water supply protection areas in Albemarle County, VA (Clark 2001).

Another issue related to division and development of the watershed land is the parcel size. In rural areas, small parcels are a concern because they cannot support agriculture or forestry. They also lead to a higher percent imperviousness because there is less land relative to the impervious driveways and roofs. In Rural Area 1, the dominant new parcel size is between two and five acres and the large majority of new parcels are less than 21 acres (Figure 23). By contrast, and by design, nearly all the new parcels in the Crozet development area are less than 2 acres (Figure 24). Crozet is achieving the desired densities, but widespread division of large parcels is still occurring in the portion of the SFRR Watershed designated for rural protection.

Farmland acreage is declining in Albemarle County and presumably the SFRR Watershed as well (Figure 25). Of course, the fate of farming has to do with much more than County planning. Farming is subject to national and international economic trends.

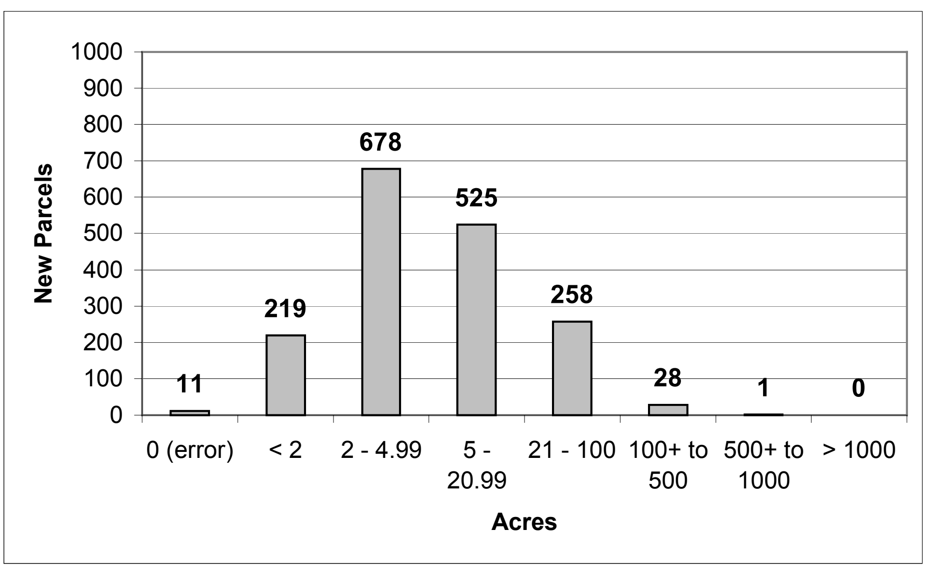


Figure 23. Sizes of new land parcels created between 1985 and 2000 in Rural Area 1 (approximating the South Fork Rivanna Watershed) of Albemarle County, VA (Clark 2001).

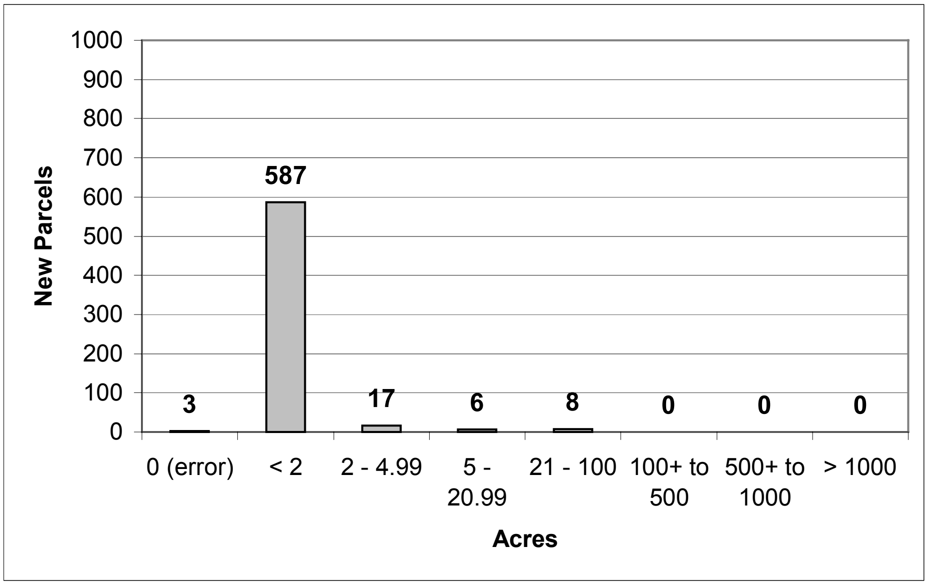


Figure 24. Sizes of new land parcels created between 1985 and 2000 in the Crozet Designated Development Area of Albemarle County, VA (Clark 2001).

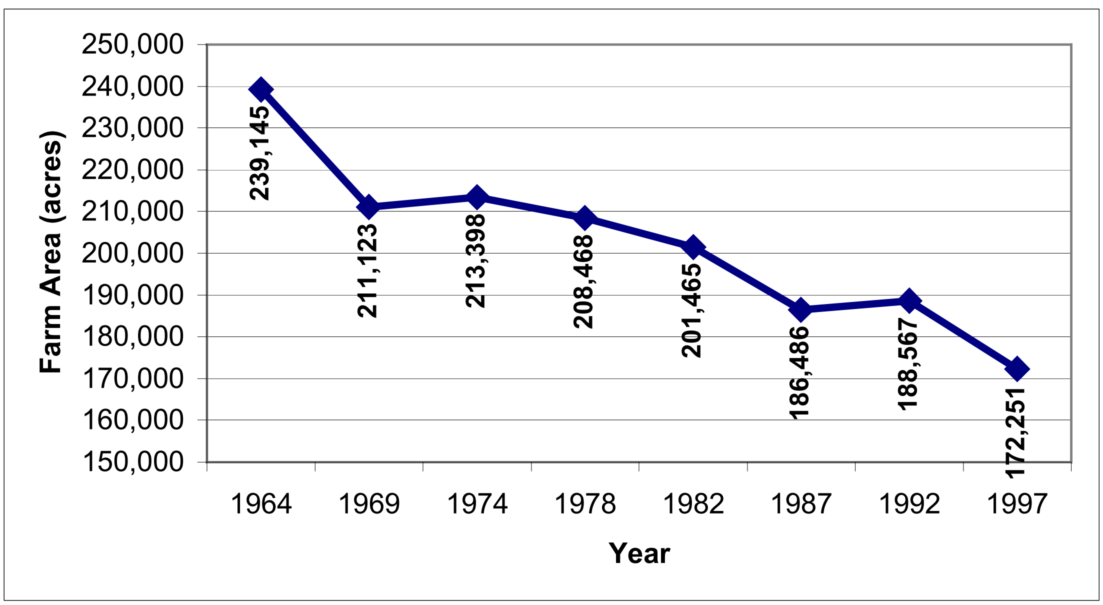


Figure 25. Total farmland acreage in Albemarle County, VA between 1964 and 1997 (Clark 2001).

Changes in the Reservoir and its Tributaries

Methods Summarized

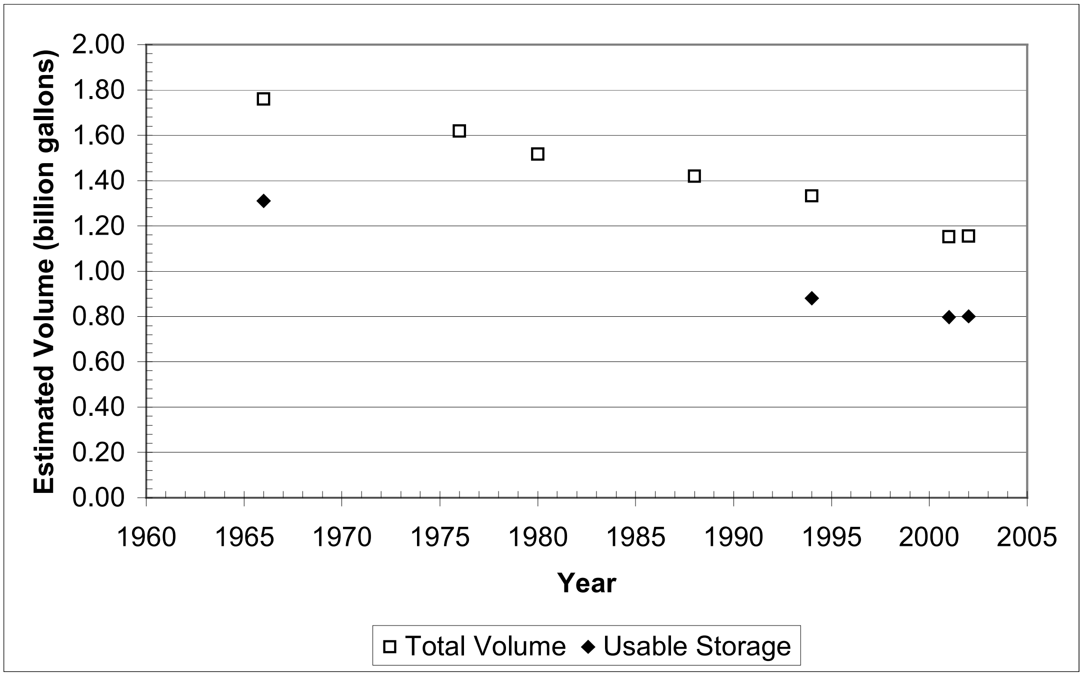
The reservoir itself has been monitored through a series of grants over the years. This monitoring was carried out by County and RWSA staff (mainly the Watershed Managers) with guidance from consultants. Limited tributary monitoring has occurred through both local efforts and the Virginia Department of Environmental Quality's routine monitoring. The only tributary data set large enough for statistical analysis comes from the Mechums River at Garth Road and is composed mainly of VDEQ data. For both reservoir and tributary samples, the period of intensive monitoring began in the early 1980s. From that starting point, this analysis extended to the mid- to late-1990s. The reservoir was monitored only during the summer months of June to September. The tributaries were monitored year round. The Mechums River data were analyzed separately for the growing season (April to September) and the dormant season (October to March). These seasons were expected to be quite different because of the effect of temperature and plant transpiration on watershed hydrology. Finally, the RWSA has had studies of the contours of the reservoir bottom (bathymetric surveys) carried out on six occasions.

Reservoir monitoring included profiles grab samples of water at 12 meter, 6 meter, and 0.1 meter depths. Most of this report deals with the surface sample data. Though three sites on the reservoir were sampled, this report addresses only the station nearest the dam and the raw water intake. Nutrient, algae, and other measurements were made by the Rivanna Water and Sewer Authority laboratory or its contractors (Bowler 2000b, Appendix II of this report). Dissolved oxygen and temperature profiles were measured at half meter intervals from the 12 meter depth to the surface.

Tributary data came mainly from surface grab samples made by the VDEQ using its laboratory and methodology. Hydrologic data associated with tributary samples came from USGS gauging stations (USGS 1999). If the instantaneous discharge was not recorded, a daily average was substituted. Bathymetric data came from RWSA's consultants over the years (Table 11).

Sedimentation

The latest bathymetric survey, conducted in February of 2001, shows that SFFR has lost approximately 15.6 million gallons (0.92%) per year of storage capacity annually since 1966 (Figure 26). A bathymetric survey involves depth sounding to map the contours of the reservoir. Net changes in the reservoir shape indicate how much it is filling. Bathymetric survey is the best way to measure overall sedimentation rates in the impoundment. Sixteen million gallons per year is equivalent to thirty one-gallon jugs of sediment dumped into the reservoir every minute on average. (Note that sediment does not enter the reservoir at such a steady pace. Usually, the sediment load is smaller than 30 jugs per minute, but during storms, particularly large storms, it is much larger.)



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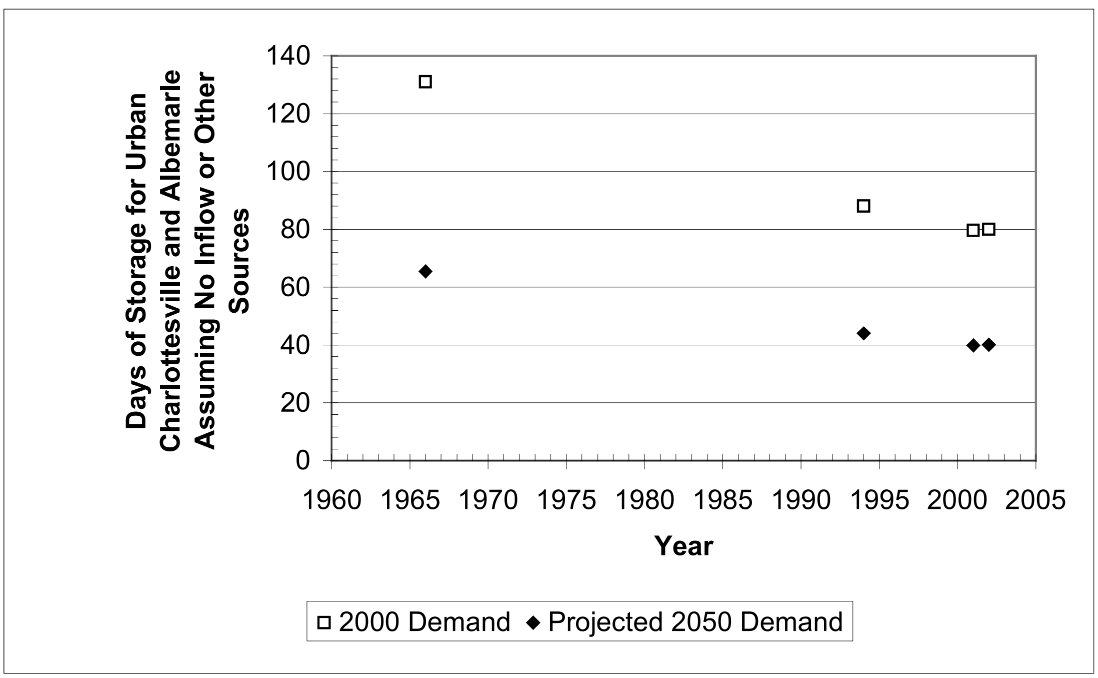

b.

Figure 26. Loss of original storage volume in the South Fork Rivanna Reservoir (near Charlottesville, VA) to sedimentation (based on bathymetric surveys) in terms of (a) reservoir volume and (b) days of urban supply assuming no other reservoir sources and no inflow (Table 11). Usable storage is water above the lowest water intake level. The “days of storage” is shown for illustration but does not represent reality. There are other reservoirs and a river intake serving the urban area and there is almost always inflow to the SFRR.

The annual rate of sedimentation has varied considerably from year to year (Table 11). Over the first ten years of the reservoir, the sedimentation rate was estimated as 8 million gallons per year (mgy). From 1976-1980 it appeared to be much higher, 25.2 mgy. The periods from 1980 to 1988 and 1988 to 1994 appeared to have had fairly consistent rates of 12.2 and 14.4 mgy respectively. The period from 1994 to 2001 produced the highest rate to date, 25.9 mgy, while 2001 to 2002 saw almost no change. The highly variable nature of these estimates suggests weather conditions are a huge factor in sedimentation and that very large storms may be particularly important.

Table 11. Rate of sedimentation in the South Fork Rivanna Reservoir (near Charlottesville, VA) based on bathymetric surveys (Potter 2001).

Study Reference	Year	Total Volume (million gallons)	Annual Sedimention Rate Since Last Survey (million gallons/year)	Annual Sedimentation Rate Since Last Survey (% of total volume)
Design	1966	1,700	(19.6 predicted over life of reservoir)	(1.15 predicted over life of reservoir)
Betz Environmental Engineers, Inc. 1977	1976	1,620	8.0	0.47
Glaspey, R.G. 1981	1980	1,520	25.2	1.48
James R. Reed & Associates, Inc. 1988	1988	1,420	12.2	0.72
Black & Veatch 1995	1994	1,330	14.4	0.85
RWSA	2001	1,150	25.9	1.52
RWSA	2002	1,155*	0.0*	0.0*

* The 2002 bathymetric survey estimated reservoir volume as slightly greater in 2002 than 2001. The estimated increase may have been the result of normal measurement error, sediment settling, or both. The results are treated here as no net increase in sedimentation.

If changes in erosion processes or land use patterns have influenced sedimentation, it is not apparent. When stream flow is taken into account, there as been no statistically significant change in sedimentation rates. It is helpful to address the topic by thinking of sediment in terms of yields, the volume of sediment delivered per unit watershed area and unit time. As stream flow increases, sediment concentration generally increases as well. If the sediment yield from the watershed was less over the years, the concentration of sediment would still increase with flow but to a lesser degree. Conversely, if the sediment yield from the watershed was greater over the years, the concentration of sediment would have increased more in relation to each high flow event in the more recent years. Based on the data available, the sediment response of the Mechums River to variation in flow has shown no significant change between the early eighties and the late 1990s (Figure 27).

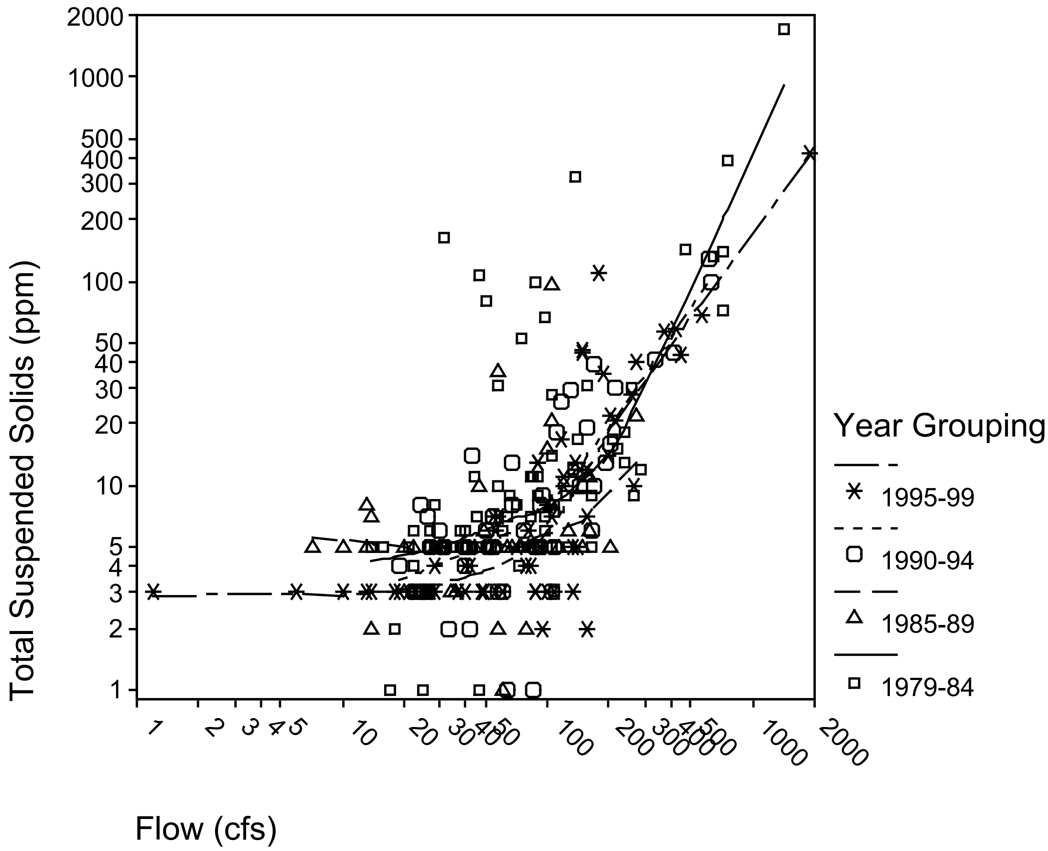

Figure 27. Total suspended solids in the Mechums River at State Road 614 near White Hall, VA shown by flow and by time period. The similarity of the (Lowess) best fit line patterns indicates the lack of change in the relationship of sediment and flow over the years.

There are various conclusions that could be made. First, it is possible that the relative contributions from the sources have changed but the overall sediment yield has remained the same. Perhaps row crop agriculture has declined as a sediment source but development has replaced it. Second, the relative contributions from the sediment sources may not have changed. This scenario would almost certainly hold true if stream banks were the major sediment source. Third, sediment loading in a large watershed is not responsive to management at time frames we are examining because larger forces of floodplain formation and erosion are taking place on the scale of decades and centuries.

As mentioned before, little is known about the relative balance of the landscape versus the stream bank sediment source. The apparent association of very large storms with periods of high sedimentation rates may provide circumstantial evidence for an important role for the stream bank. Intuitively it seems more likely that the stream channel would be more vulnerable to a disproportionately large increase in erosion above a flow threshold than that the landscape would be susceptible to a similarly large increase in erosion above a rainfall volume threshold. Intuition aside, the situation is not clear. Getting a handle on this question is critical.

Developing a better understanding of the balance between the landscape and stream bank sediment source will help to prioritize mitigation strategies and establish realistic sediment reduction expectations. Most sediment mitigation strategies in the past have been directed at landscape sediment. These include erosion and sediment control regulations and agricultural and forestry best management practices (BMPs). Landscape erosion mitigation will always be essential. In addition to helping to protect large waterways like SFRR, reducing landscape erosion protects small streams, adjacent landowners, and valuable topsoil.

The data hint that further research will show that stream bank strategies need greater attention. Strategies directed at stream bank sediment include stream buffer vegetation protection and restoration, stream bank restoration, and stormwater quantity controls. Stormwater quantity controls, primarily focused only on flood peak reduction, have traditionally done a poor job of protecting stream banks (though efforts are being made to address the problem). Stream bank restoration is usually costly and only possible at a few, high priority sites (such as where valuable property is threatened). Stream buffer enhancement is a strategy of growing importance. Though the erosion reduction from buffer enhancement may be less than that of stream bank restoration, the cost is dramatically lower making it possible to cover much greater lengths of stream. (Stream buffers also provide other ecological benefits such as shade, food, and habitat to the stream and filtering of landscape sediment.) Finally, if the stream bank source is dominant, the reality may be that only very modest sedimentation mitigation is achievable.

Nutrients

Total phosphorus concentrations near the surface of SFRR at the dam have decreased from 0.045 ppm in the early1980s to 0.027 ppm in the middle 1990s or 40% (Figure 28). Phosphorus concentrations were lower after 1988 than before. 1988 was the year the Crozet sewage interceptor was completed and the hydropower plant went online. (Trends in the tributary concentrations were impossible to analyze due to changes in VDEQ laboratory methods.)

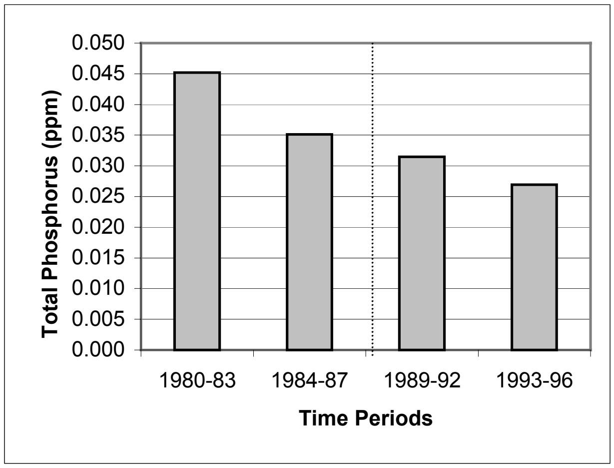

Figure 28. Total phosphorus concentrations at the surface near the dam in the South Fork Rivanna Reservoir near Charlottesville, VA by time period. The dashed line divides the pre-1988 and post-1988 periods.

Several factors could be at play in the reduction in reservoir phosphorus concentrations. Certainly the Crozet sewage interceptor was expected to reduce phosphorus entering the reservoir. Much of the phosphorus that once flowed from Crozet into the SFRR Watershed (25% or more of the load) has been removed from the watershed and treated at the Moore's Creek Wastewater Plant since 1988. The Moore's Creek Plant is well below the reservoir. The state ban on phosphates in detergents may have reduced phosphates from septic systems and other sources. The application of agricultural best management practices (BMPs) on farms and erosion and sediment control measures on construction sites may have reduced nonpoint source phosphorus loads. Lickinghole Basin may have removed a small portion of the nonpoint source loads from that watershed. An unintentional, but likely source of reduction is the decline of row crop agriculture in the watershed in response to general economic forces. There may be other possible causes as well. There is no way to assign the reduction precisely to the various changes in the watershed and its management, but the reductions are a positive step for source water protection.

The nitrate/nitrite levels did not decline in the smooth pattern of the phosphorus concentrations, but they appeared to be down as well. Nitrogen levels (in the form of nitrate and nitrite) appear to be down in the reservoir near the surface and near the dam. Values fell from 0.157 ppm in the early 1980s to 0.050 ppm in the middle 1990s (Figure 29). In the Mechums River at Garth Road, there was a significant reduction in total nitrogen (which also includes organic forms of nitrogen) between the early 1980s and late 1990s during the growing season (Figure 30). This result matches the finding of sampling within the reservoir for generally the same portion of the year. There was no significant change in Mechums River total nitrogen concentrations during the dormant season.

While nitrogen is only rarely the limiting nutrient in the reservoir, the apparent decline is a sign of general water quality improvement and a benefit to the Chesapeake Bay. The likely causes for any nitrate/nitrite or total nitrogen reductions are essentially the same as those for the phosphorus reduction with the exception of the phosphate ban.

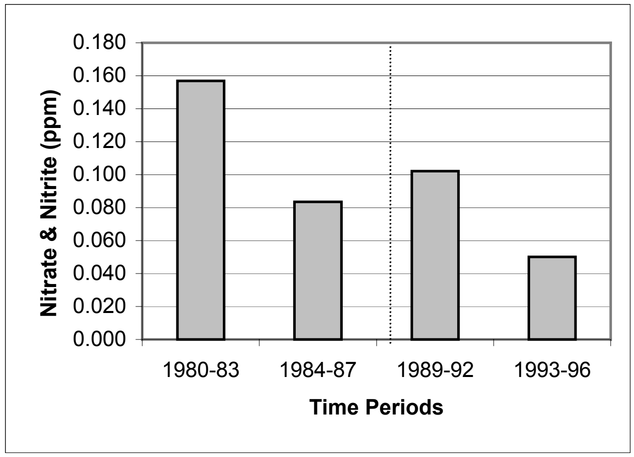

Figure 29. Nitrate/nitrite concentrations at the surface near the dam in the South Fork Rivanna Reservoir (near Charlottesville, VA) by time period. The dashed line divides the pre-1988 and post-1988 periods.

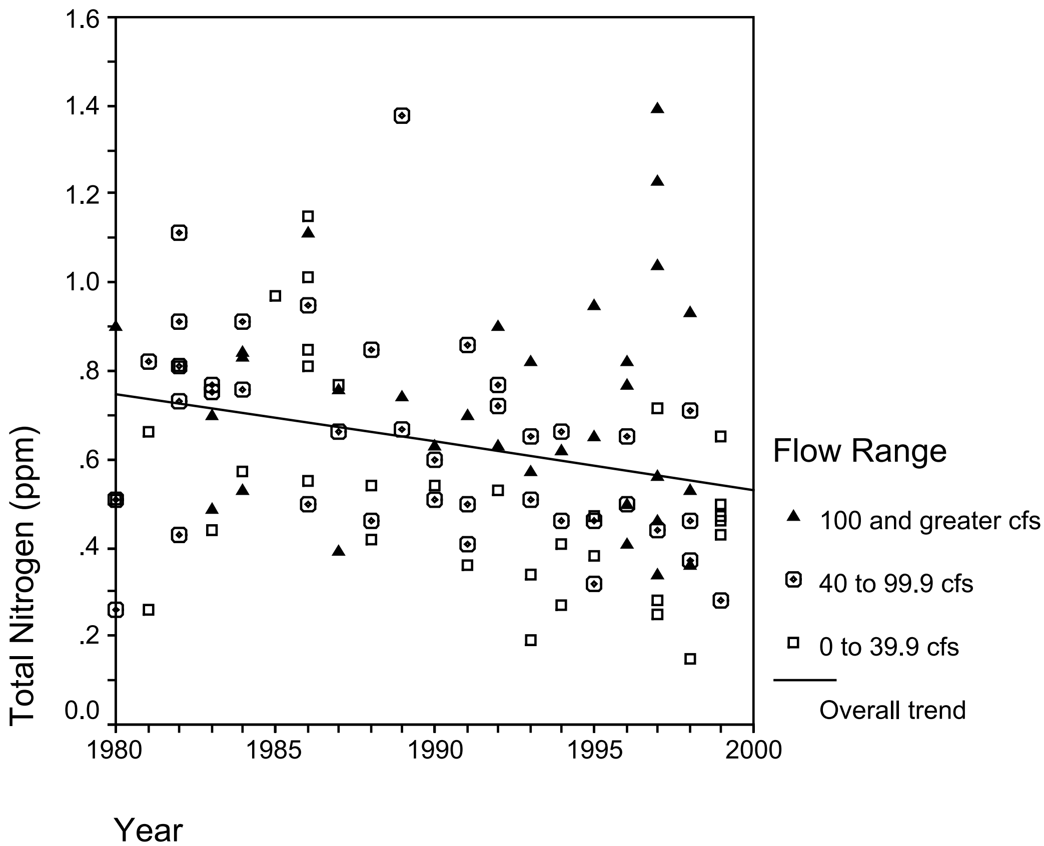

Figure 30. Growing season total nitrogen concentrations in the Mechums River at State Road 614 near White Hall, VA by year and flow range.

Algae

With nutrient levels going down, it would seem the algae community should be reduced. Unfortunately, it may not be so. Between the pre-1988 period and the post-1988 period, the number of algae went up from 7,688 cells/ml to 16,440 cells/ml (Figure 31). It is important to note that cells/ml is not the same as biomass, the best measure of the dominance of the algal community. A population could be composed of many small cells adding up to a lower biomass than a population with a few large cells. It is biomass that is limited by nutrients more than cell number. In fact, there is some contradictory indication that cell biomass is steady based on chorophyll a concentrations. Chlorophyll is needed by algae to photosynthesize. The concentration of Chlorophyll a is a good surrogate for biomass. Unfortunately, in this case, the chlorophyll a data set is quite small.

Another algae characteristic to consider is the community composition. Here again there is a conflict with the positive news on phosphorus. There are many different kinds of algae organized in a few groups. One group that is considered to be an indicator of eutrophication and poor water quality is the blue-green algae. These organisms are part algae and part bacteria and have characteristics that give them a competitive edge in tough conditions. While there is not a clear trend, the blue green algae do appear to be a bigger portion of the algae community in recent years. They increased from 75% of the community before 1988 to 96% after 1988 (Figure 32).

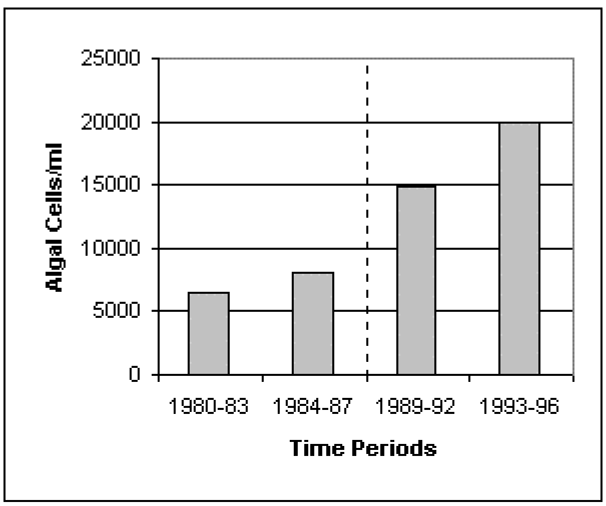

Figure 31. Algae concentration at the surface and near the dam in the South Fork Rivanna Reservoir near Charlottesville, VA by time period. The dashed line divides the pre-1988 and post-1988 periods.

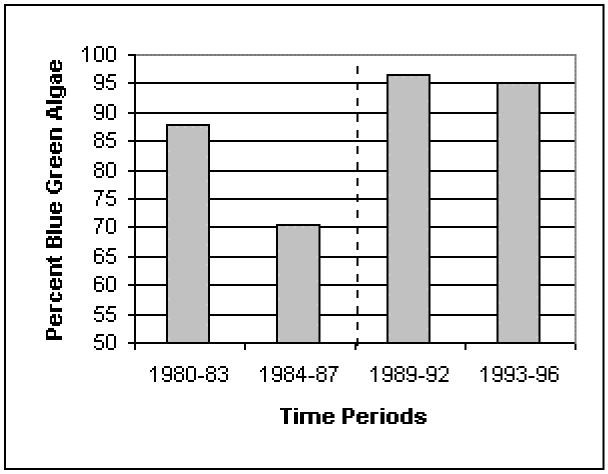

Figure 32. Blue green algae as a percentage of all algae at the surface and near the dam in the South Fork Rivanna Reservoir near Charlottesville, VA by time period. Many blue green algae taxa are considered nuisance algae. The dashed line divides the pre-1988 and post-1988 periods.

Possible Explanations for the Nutrient - Algae Paradox

It is difficult to know why changes in the algae do not appear to be paralleling the nutrients. The experience of RWSA staff is quite to the contrary. Over the years they have found algae to be much less of a problem then in the early 1970s and have not had to use copper sulfate, an algae treatment used in reservoirs, for years. There are several possible explanations for the seeming paradox:

- The result is legitimate, but treatment strategies have advanced to a point where algae problems are more easily eliminated.
- A lack of sufficient algae data is producing a misleading result. A shift in the algae community to algae with higher numbers but not necessarily greater biomass has occurred. Better measures of biomass are needed.
- The algae community is subject to a physical rather than a nutrient limitation (discussed below).
- A nutrient other than phosphorus or nitrogen is the limiting factor.
- The algae problem of the early 1970s was largely eliminated before monitoring began in earnest in the 1980s. Since monitoring began, algae may have increased, but not enough to bring back the previous problems.
- The abandoned reservoir aeration system was a greater factor than generally believed.
- There are factors that have not been measured that explain the paradox.

Weather conditions are probably not the explanation because they were accounted for in the statistical analysis (Bowler 2000b). At this time the paradox goes unexplained.

There is some evidence of a physical change as a factor. A major physical change in the reservoir was the installation of a hydropower facility in 1988. This addition certainly would have changed the flow path of the water through the reservoir, perhaps enough to influence the algae. The hydropower plant intake is on the bottom of the reservoir, 100 yards or so in front of the dam. When the plant is operating, it takes cool water from the bottom of the reservoir, leaving the layer of warm water on the top. This upper layer of water might flow over the dam more slowly because of the bottom withdrawal for the hydropower plant. The algae live in the warm, surface layer where sunlight is accessible. Previously it was mentioned that water in the SFRR typically has a residence time of six to eight days except when a significant storm flushes the reservoir more quickly. It is possible that by keeping the surface layer in the reservoir longer, the residence time for the algae has increased beyond six to eight days giving the algae more time to use whatever nutrients are available to increase their population.

Temperature profile data support the speculation that there was a physical change around 1988. The maximum temperature in the reservoir for the four years before 1988 was 76.6°F. In the four years after 1988 it was 80.1°F (Figure 33). The longer the water is on the surface of the SFRR, the more potential it has to heat up. A better indicator of stratification of the water is the difference between the warmest and coolest temperature in the water column. In the four years before 1988, this difference was 4.7°F. In the four years after 1988, the difference was 6.1°F (Figure 34).

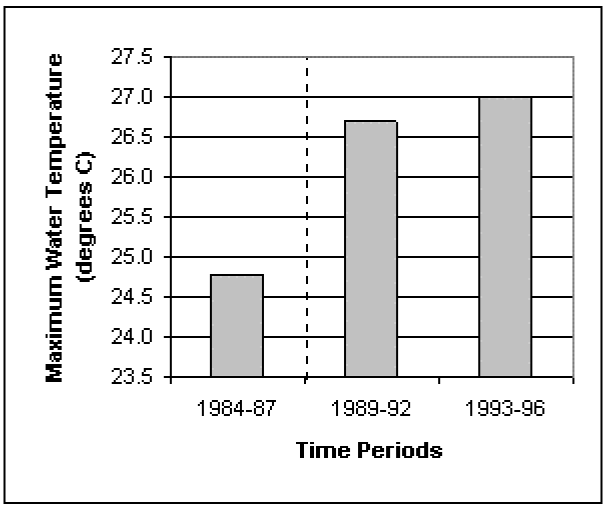

Figure 33. Maximum water temperature in the water column in front of the dam of the South Fork Rivanna Reservoir (near Charlottesville, VA) by time period. The dashed line divides the pre-1988 and post-1988 periods.

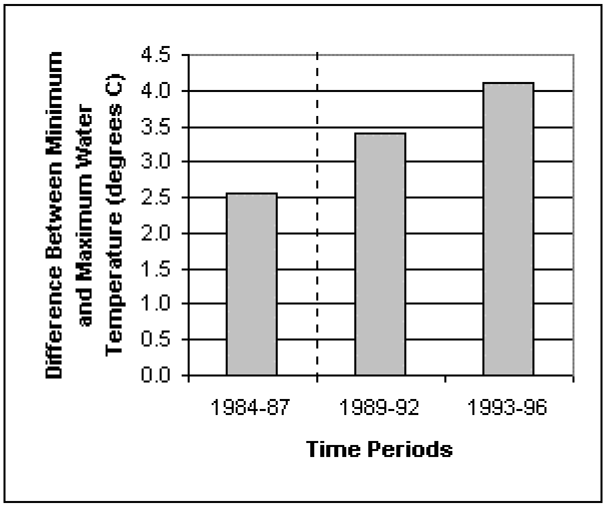

Figure 34. Difference between maximum and minimum temperatures in the water column in front of the dam of the South Fork Rivanna Reservoir (near Charlottesville, VA) by time period. The dashed line divides the pre-1988 and post-1988 periods.

The argument for a physical limitation also gains anecdotal support from the fact that the water treatment plant operators believe that use of the hydropower plant helps them manage sediment after summer thunderstorms. Their strategy is as follows. After these storms, cool rainwater entering the reservoir sinks below the warm surface water. This water brings with it a heavy load of suspended sediment that will have to be removed at the treatment plant. By operating the hydropower plant at full capacity some of the cool, sediment-laden water is removed from the bottom of the reservoir. The raw water intakes that are much higher in the reservoir do not receive as much of the most sediment-laden water making treatment easier. (No storage is lost because water is flowing over the dam as well as through the hydropower plant during these events.)

Enrichment

The overall question of whether the SFRR is more or less eutrophic (enriched) is surprisingly difficult to answer. One way to consider it would be to look at the levels of dissolved oxygen. Low dissolved oxygen is a major outcome of eutrophication. These data are very unclear. The mean dissolved oxygen in the water column went up quite a bit between the middle 1980s and the early 1990s then back down in the middle 1990s to a point below that of the middle 1980s.

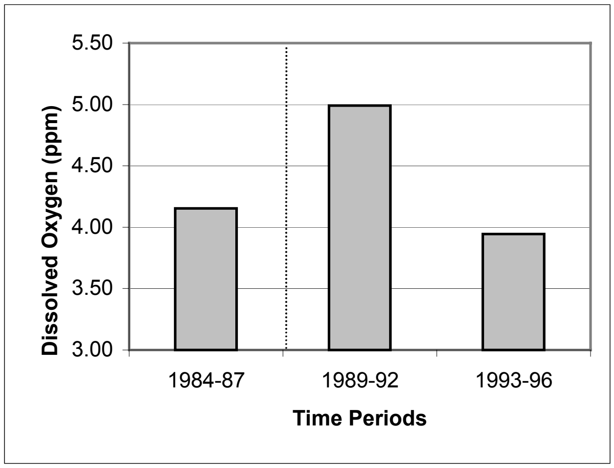

Figure 35. Mean dissolved oxygen concentrations in the water column in front of the dam of the South Fork Rivanna Reservoir (near Charlottesville, VA) by time period. The dashed line divides the pre-1988 and post-1988 periods.

Some limnologists use a statistic called the Carlson Trophic State Index (TSI) to measure eutrophication (Carlson 1977). This index theoretically can range from 0 to 100 and allows those who monitor lakes and reservoirs to assess eutrophication using phosphorus concentration, chlorophyll a, or water clarity (secchi disk depth). Through a mathematical process, the index is supposed to put these three systems of measurement on the same scale. Lower values indicate a lack of enrichment. Values from 51 to 65 indicate a eutrophic state. Values above 65 indicate an extremely eutrophic (or hypereutrophic) state (Carlson 1977). By all measures, the reservoir is somewhat, but not extremely eutrophic (Figure 36).

Applying this index to the SFRR highlights the complex and riverine nature of the reservoir (Figure 36). Using phosphorus as the measure, the SFRR has improved quite a bit (as discussed above). Using chlorophyll a, it hasn't changed much and is barely eutrophic (based on a very small data set). Using water clarity, SFRR hasn't changed much but is quite eutrophic. The water clarity overestimates the state of eutrophy because the river-like reservoir carries a high sediment load. The index is meant to measure the impact of algae on water clarity. However, it does not distinguish mineral sediment from algae.

A very important measure is how the reservoir condition has effected water treatment. Water treatment plant operators perceive algae problems in recent years as moderate and manageable. They see treating turbidity from sediment as a larger problem (Golloday 2000).

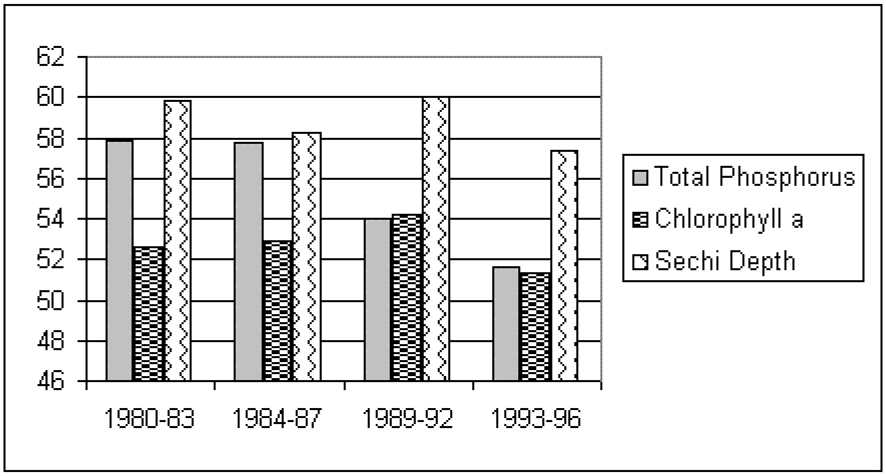

Figure 36. Carlson Trophic State Index values for the surface water in front of the dam of the South Fork Rivanna Reservoir (near Charlottesville, VA) by time period and method of estimation.

As a final note, fish kills have not occurred since the early 1970s. Those fish died because of lack of oxygen at night. The following is a plausible explanation. In the early 1970s, not long after the reservoir was filled, it was subject to three potentially large sources of food for oxygen-consuming bacteria. First, it was subject to whatever organic matter was in the reservoir when it was filled. Second, it was subject to the organic matter flowing into the reservoir from point sources in the tributaries, particularly the food processing discharge at the Morton Frozen Foods facility in Crozet. Third, it was subject to the supply of organic matter provided by the algae in the reservoir which grew in huge numbers using the phosphorus flowing in from both point and nonpoint sources. The bacteria consumed dissolved oxygen as they processed the organic matter. Also the algae which produced oxygen in the day consumed it during both day and night. Because of the oxygen consumption, probably combined with dry weather, dissolved oxygen levels dropped to the point where fish kills occurred. The kills occurred at night because photosynthesis, which would counter oxygen consumption by bacteria and algae with oxygen production by algae, does not take place in the dark. Aesthetically it became clear to everyone that the reservoir was in a poor state. Taste and odor problems in the drinking water were attributed to algae and addressed through copper sulfate application.

What changed? First, it is possible that as the reservoir matured, the resident organic matter was consumed or buried by sediment. Second, the imposition of federal Clean Water Act (CWA) regulations and other measures led to reductions in the organic load from point sources including Morton and others. Third, the CWA regulations led to reductions in point source nutrient loads leading to reduced algae blooms and cutting down the organic load. The lack of fish kills in recent years is a sign that eutrophication has moderated since the early 1970s. The decrease in nutrient concentrations since monitoring began in earnest in the early 1980s, as result of the Crozet sewage interceptor and other factors, is a sign of continued improvement in water quality though the influence on eutrophication is less clear.

Chlorides

Chloride concentrations were monitored by VDEQ in the Mechums in the 1990s. During that time the concentrations appear to have increased significantly both during the dormant season and growing season (Figure 37). The concentrations of chlorides observed (roughly 3-8 ppm) are far below the USEPAs secondary drinking water standard of 250 ppm (AWWA 2001). However, chlorides can be a general indicator of several watershed issues including increases in road salt application, failing septic systems, and general urban runoff. The trend is worthy of attention.

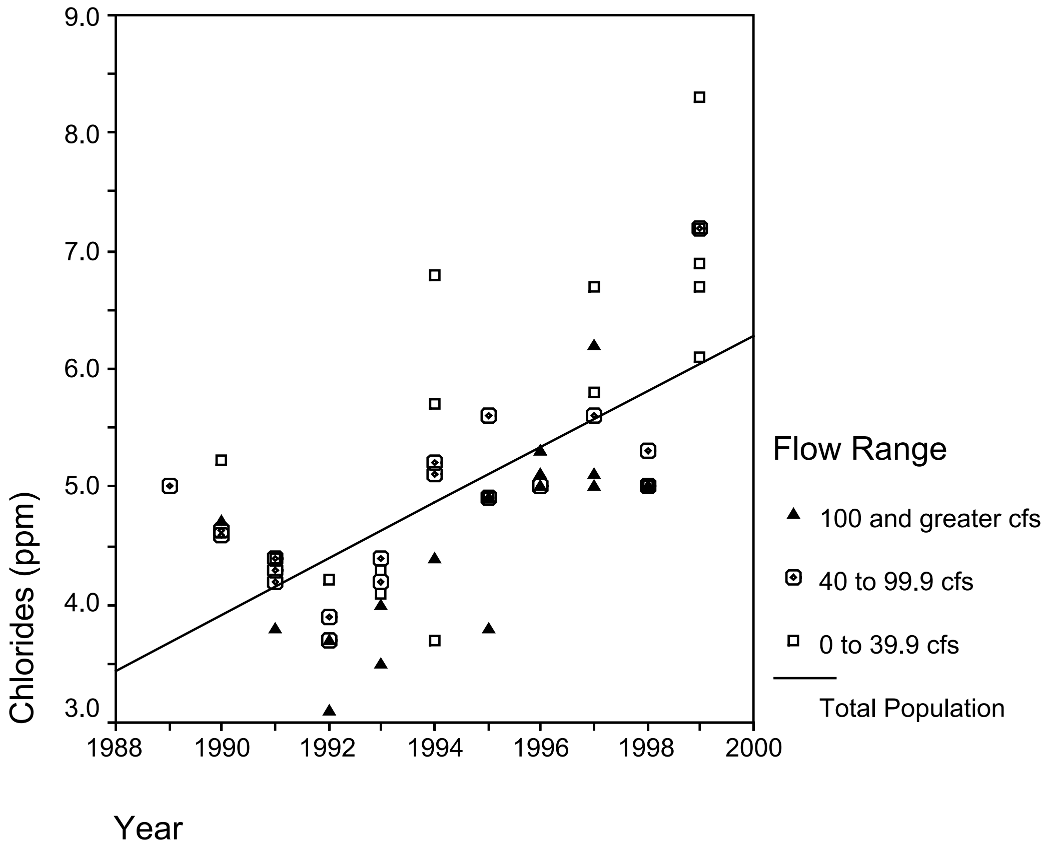

Figure 37. Growing season chloride concentrations in the Mechums River at State Road 614 (near White Hall, VA) by year and flow range.

Pollution Monitoring Results Related to Management Efforts

Reductions to point sources of pollution have been greater than reductions to nonpoint sources. In this way, the SFRR Watershed is a microcosm of national water quality protection efforts. It is impossible to assign the pollution load reductions to specific efforts. The size of the watershed makes this practically impossible without very costly monitoring. However, at least three lines of evidence suggest the assignment of the bulk of reductions to point sources. First, because of the nature of its chemistry, phosphorus from nonpoint sources tends to travel bound to sediment. However, it appears that sediment yields have not been reduced. These two findings hint that the bulk of phosphorus reduction came from point source reductions such as the Crozet interceptor. Second, the seasonal nature of the nitrogen reduction points to more significant gains with point sources. Total nitrogen concentrations were significantly lower only in the growing season when stream flows tend to be lower, and point source contributions make up a higher proportion of the total load. Third, the increase in chloride concentrations in the 1990s may indicate increasing nonpoint sources of pollution.

It is important to note that not all actions listed in the watershed management timeline would lead to measurable declines in pollutant loads to the reservoir (Table 12). For example, down zoning was intended to minimize future impacts, but would not affect existing pollution sources. Stormwater treatment requirements and erosion and sediment control standards would be expected to moderate pollution from future development, but would not affect past development. On the other hand, some actions might be related to actual improvements in current conditions of the reservoir. For example, the Crozet interceptor was intended to remove about a quarter of the phosphorus load out of the SFRR Watershed immediately. Agricultural Best Management Practices (BMPs) and the Lickinghole Creek Stormwater Basin were intended to reduce existing pollution problems as well.

Table 12. Possible relationships between management changes (local, state, and federal) and the water quality of the South Fork Rivanna Reservoir (near Charlottesville, VA). "Y" indicates it would influence that type of pollutant. "N" indicates it would not.

Change	**Year Completed**	**Pollution that the Change Might Reduce**				
		Point Source	Nonpoint Source	Sediment	Phosphorus	Nitrogen
Clean Water Act	1972	Y	N	N	Y	Y
Crozet Interceptor	1988	Y	N	N	Y	Y
VA Phosphate Ban	1988	Y	Y^	N	Y	N
General Decline in Row Crop Agriculture	Overall	N	Y	Y	Y	Y
Agricultural BMPs	1993*	N	Y	Y	Y	Y
Highway BMPs	1993	N	Y	Y	N	N
Lickinghole Basin	1993	N	Y	Y	Y	Y

*These BMPs were installed between 1989 and 1993 as part of an EPA grant. Other BMPs have been installed in more recent years using other funding sources.
^Septic systems can be considered nonpoint sources.

Conclusions

Land Use

The stated justification of the 1980 rezoning effort was that it would help to achieve the complementary goals of rural preservation and water quality protection. In spite of the rezoning and policy changes, there has been a pattern of conversion of rural land to suburban land use. The trend is toward relatively small parcels and a decline in farm acreage. The SFRR Watershed has a growth rate higher than average for designated rural areas but somewhat lower than designated growth areas.

Sedimentation

Sediment loads have varied greatly over the years, presumably with weather, but the yield relative to the storm intensity has not changed in a measurable way. The sources of sediment in SFRR and potential mitigation strategies are complex and poorly understood. Developing a greater understanding of landscape versus stream bank source contributions and the importance of extreme storms will help to calibrate sedimentation reduction strategies and expectations. Enhancement of stream buffer vegetation is a strategy at hand immediately. Traditional landscape sediment mitigation (erosion and sediment control and agriculture and forestry best management practices) will continue to be important.

Enrichment and Related Issues

Since monitoring began in the early 1980s, phosphorus concentrations in the reservoir clearly are down (about 40%). Nitrogen concentrations appear to be down as well. The main source of this improvement was probably the Crozet sewage interceptor installed in 1988 in addition to a gradual decline in row crop agriculture, a state-wide ban on phosphate detergents, installation of agricultural best management practices (BMPs), and construction of the Lickinghole Creek Stormwater Basin. The nutrient reductions in the 1980s and 1990s may have built upon other, unmeasured reservoir improvements in the middle and late 1970s that resulted from the federal Clean Water Act and reservoir maturation. Since the late 1980s, operation of the hydropower plant or some other factor may have led to increases in the algae community in spite of the phosphorus reductions. If algae have increased, the issue has not translated into significant water treatment problems. Had the phosphorus reductions not occurred, it is possible that the algae problems present prior to the 1980s would have reoccurred.

Toxins, Metals, and Pathogens

The drinking water is free of problems with chemicals or pathogens. The initial study of the SFRR reported in 1977 that there were no significant problems with metals or other potential toxins in the reservoir (Betz Engineering 1977). There is no reason to believe there has been any change in this status. The finished water is comprehensively analyzed annually and is meeting all standards. Despite little evidence of problems, this issue should always be monitored. Similarly, the finished water is free of pathogens. However, pathogens in the raw water should be minimized.

Overall

The SFRR Watershed is a microcosm of water quality in the United States. Significant gains have been made with point source pollution. The effort to reduce nonpoint source pollution has proven more difficult. It is almost as difficult to study nonpoint source pollution as it is to control it. Data on development activity and on chloride concentrations suggest that nonpoint source pollution will continue to be a problem. Few, if any, point source solutions remain. Since 1988, nonpoint source pollution has been the main target of watershed management. It will continue to be the thrust of both management and monitoring, particularly in light of the fact that sedimentation is almost exclusively a nonpoint source problem.

UPDATING THE 1979 WATERSHED MANAGEMENT PLAN

The Time Has Come

The time has come to update the original Watershed Management Plan which is now more than 20 years old (Appendix I). First, the Water Supply Project, with its 50-year planning horizon, soon will be moving into the permit application phase. All indications are that the SFRR will be integral to the suite of water supply solutions. The Water Supply Project deals with water quantity and requires a complementary effort to preserve and improve water quality. Second, after many years of watershed management and study, there is a great deal of local expertise to apply to improving watershed management. Third, the community has also changed a great deal over that time period. Finally, the tools of watershed management in general have evolved significantly over the past 23 years.

Like the original plan, an update will benefit from the input of the wide range of interested and affected parties. Many of the 1979 recommendations still hold. Others need to be reconsidered. New recommendations will be needed. The starting point for a new plan will be the 1979 plan and community planning documents developed in more recent years.

Supporting Watershed Management Documents

Appendices I and II contain reports and report summaries from a number of efforts related SFRR and related resources. In embarking on any new planning process, it will be essential to take stock of and build upon all the hard work of the past.

1979 South Rivanna Reservoir Watershed Management Plan (Appendix I)

The 1979 plan laid out particular steps that could be taken to manage the watershed in a way that would protect the reservoir (F.X. Brown Associates, Inc. and Watershed Management Plan Committee 1979). It recommended staffing to support those efforts. Finally, it recommended water quality monitoring to track the success of the efforts. The 1979 plan is reproduced in Appendix I. Commentary on how specific items have evolved over the years is provided.

Results of a September 2002 Meeting on the History and Future Management of the South Fork Rivanna Reservoir and Watershed (Appendix I)

On 4 September 2002 a public meeting was hosted by the RWSA and Albemarle County to discuss the findings of this report and the concept of updating the 1979 plan. A meeting summary is provided in Appendix I.

Rivanna Water & Sewer Authority Revised Staff Recommendation: A Multi-Step, Integrated Water Supply Strategy, Urban Water Service Area (Appendix II)

In the fall of 2002, the RWSA Board of Directors, after endorsement by the Charlottesville City Council, Albemarle County Board of Supervisors, and Albemarle County Service Authority Board of Directors, approved a water supply strategy. A key element was continued emphasis on the SFRR. Approval of the strategy allowed the first steps of implementation to begin.

Water Supply Project Summary (Appendix II)

The Water Supply Project has led to a set of recommendations from the consultant presented in *Revised Draft Rivanna Water and Sewer Authority Water Supply Project Summary of Recommended Alternatives* (VHB 2001a). The recommendations involve continued use of SFRR as the dominant water supply for Charlottesville and Urban Albemarle for years to come.

Water Resources in the County of Albemarle Comprehensive Plan (Appendix II)

The principles, goals, objectives, strategies, and standards laid out in the County of Albemarle Comprehensive plan should instruct future watershed management planning (Albemarle County 1999). The County Comprehensive Plan devotes a good deal of attention to public water supply. It also places water supply planning in a county and regional context. The hydrologic link between groundwater and surface water is emphasized. The connection to neighbors (particularly downstream neighbors in the case of SFRR) is described. The responsibility of all citizens to contribute to water resource protection is discussed.

Recommendations Regarding Sedimentation from the Thomas Jefferson Water Resource Advisory Committee (Appendix II)

A special problem discussed in many venues is sedimentation of SFRR, area streams, and the Chesapeake Bay. One of the most vexing aspects of this issue is that there is little understanding of the relative contribution from the sources of the sediment, much less the solutions. Nobody knows what portion of sediment comes from the landscape versus the stream banks or what the most appropriate reduction strategies should be. The Water Resource Advisory Committee, a technical advisory committee organized by the Thomas Jefferson Soil and Water Conservation District and the Thomas Jefferson Planning District Commission, has considered ways to address these questions (TJWRAC 2001). This work could lead to a major project for the community and the region. Seeking funds for such a study should be a priority.

Recommendations of the Rivanna Basin Project (Appendix II)

This report was prepared by a stakeholder roundtable (the Rivanna Basin Roundtable) under the guidance of the Thomas Jefferson Planning District (RRBR 1998). It was informed by a major, two-year citizen monitoring effort. The report includes many recommendations for protection of the Rivanna River and its watershed. Most of these recommendations are relevant to protection of the SFRR.

County Staff Information on Watershed Management (Appendix II)

This section provides excerpts from presentations on watershed management made by County staff in recent years. The excerpts provide general thoughts on the topic that might be helpful.

Summaries of Old Reports and Technical Information (Appendix II)

Summaries of several past consultant and staff reports analyzing reservoir and watershed issues are provided. Also, included is information on the technical analyses supporting the report.

Albemarle County Water Protection Ordinance (On the Internet)

The Albemarle County Water Protection Ordinance (WPO), Chapter 17 of the County Code was passed in 1998. It is a major component of current watershed protection efforts. It combined and updated Albemarle County's erosion and sediment control, stormwater, and stream buffer ordinances. The ordinance will continue to be a tool of watershed management and will be subject to further refinement as additional lessons are learned. The WPO is available from the Albemarle County web site (www.albemarle.org).

Available Watershed Management Tools

There are many tools that can be used in watershed management planning for SFRR. A few major tools are described here. Though these items are important, no additional information on them is provided in the appendices.

Albemarle County Rural Area Plan

The County of Albemarle is in the process of updating its Rural Area Plan. Because most of the SFRR Watershed is designated as rural area, development of this plan is key to the future of water quality in SFRR.

Land Protection Initiatives

The past few years have brought major developments in the area of open space and conservation easements (Figure 38). The Virginia Outdoors Foundation (a quasi-governmental agency) and the Piedmont Environmental Council (a private non-profit group) have been successful in promoting open space easements including several in the SFRR Watershed. The County of Albemarle is in its first year of purchasing open space easements through its Acquisition of Conservation Easements (ACE) ordinance. The County ordinance is based on the Virginia Outdoors Foundation model. The Thomas Jefferson Soil and Water Conservation District (after recent a change in state law) has started accepting conservation easements, particularly on riparian land.

There is great variability in what easements protect. Some easements are targeted at division rights. They guarantee that large parcels will not be subdivided. Other easements may or may not address division rights, but they specifically protect the land against uses that are antithetical to natural resource (in this case water quality) conservation. A conservation easement, for example, might specifically state how wide stream buffers should be or how logging should be carried out near streams. Open space easements, by protecting large parcels, should be a great help to source water protection. For example, on a large scale they should reduce the number of septic fields, roads, and houses in the watershed. However, conservation language can be necessary to specifically address water quality problems. Of course, the two types of protections can be combined into one easement in many cases.

Land that is owned outright by the public provides opportunities for water quality protection as well (Figure 38). Forested local and federal parks in the SFRR Watershed are already serving this function. The RWSA Board of Directors has recently decided to emphasize conservation practices on the land owned for a possible future Buck Mountain Reservoir that will protect the existing SFRR in the interim (Bowler 2000a).

Agricultural Cost-Share Programs

As was the case back in 1979, the approach to farm-related water protection currently is voluntary rather than regulatory. Several cost-share programs exist to assist farmers in protecting stream buffers and installing best management practices to protect water. These programs are administered by state and federal agricultural agencies including the Thomas Jefferson Soil and Water Conservation District (state, VDCR), Agricultural Extension Service (state, VA Tech), and Natural Resources Conservation Service (federal, USDA).

A particularly promising program is the Conservation Reserve Enhancement Program or CREP. In this program federal, state, and private (Chesapeake Bay Foundation and Ducks Unlimited) dollars have been combined to rent farmland for waterway buffers. In most cases, the farmers can make more money by entering the cost-share program on the riparian land than by farming it.

Farmers have reported that a major barrier to entering cost-share programs is the bureaucratic red tape. In some cost-share programs, more money is needed. These and other problems will continue to need to be addressed to get the most out of these programs.

The Chesapeake Bay Program

Many goals for SFRR Watershed will overlap with goals for the Chesapeake Bay. The Chesapeake 2000 Bay Agreement ("C2K," Chesapeake Bay Program 2000) has numerous goals which involve a major role for local governments (and utilities). There should be opportunities for partnership.

One regional manifestation of the Chesapeake Bay Program effort is the *James River Tributary Strategy* (Commonwealth of Virginia 2000). This report is a planning document for the entire James River Watershed in which the Rivanna is a major tributary. It was prepared by agencies of the Commonwealth of Virginia through a public process. It is part of the Commonwealth's commitment to the EPA Chesapeake Bay Program. Among other things, it calls for a 9% reduction in sediment from 1985 levels by 2010.

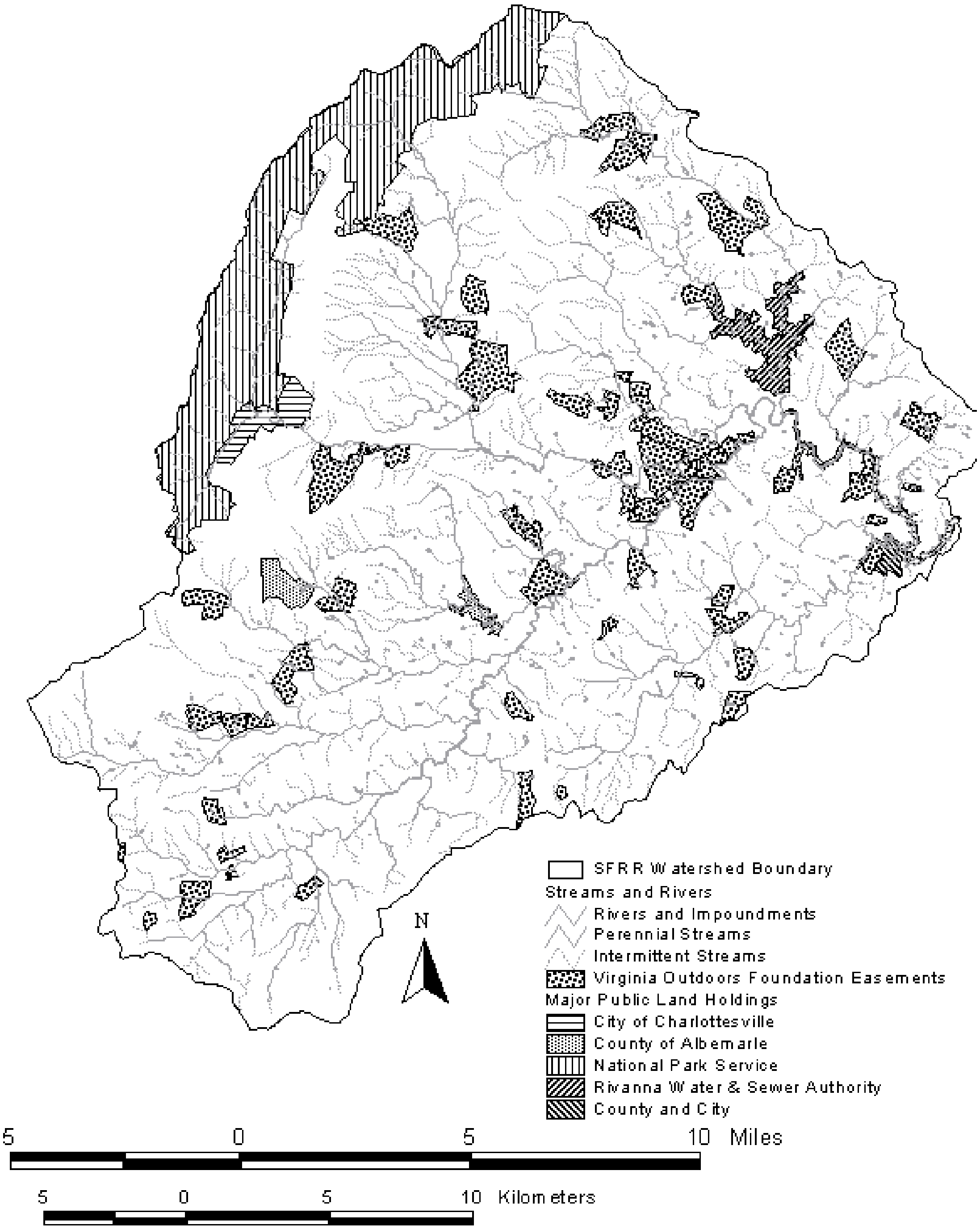

Figure 38. Protected land in the South Fork Rivanna Reservoir Watershed near Charlottesville, VA (PEC 2002, Albemarle County Office of Geographic Data Services 2000-02).

Total Maximum Daily Loads

Total maximum daily loads or TMDLs describe a planning strategy required in the original Clean Water Act (CWA) that has only recently received much attention. Segments of streams and rivers that do not meet certain water quality goals under the CWA are added to a non-attainment list. Once on the list, the pollutant causing the non-attainment must be identified. Next, the total load of the pollutant that the waterway can assimilate and be in attainment must be estimated. Through a community planning process, the maximum load is supposed to be allocated to the different sources in the watershed. The specifics of the federal and state regulations are being developed. The SFRR could be the beneficiary of the process if the TMDL planning serves some of the same water protection goals as the community's source water protection efforts.

The 2002 TMDL list included one segment upstream and one segment downstream of the SFRR (Table 13). Ivy Creek, an SFRR tributary was listed for occasional high concentrations of fecal coliform bacteria. (These bacteria have never been detected in the treated drinking water.) A stretch of the Rivanna River, beginning roughly three river miles downstream of the SFRR, was listed as impaired based on the condition of the community of stream organisms living on the bottom of the stream (benthic organisms).

Table 13. Stream segments upstream or downstream of the South Fork Rivanna Reservoir (near Charlottesville, VA) appearing on the 2002 TMDL list.

Stream	Location of Listed Reach	Clean Water Act Goal and Status	Cause of Impairment Listing
Ivy Creek	The 5 miles upstream from the confluence with Little Ivy Creek (which is roughly ½ mile downstream of Route 250).	Swimmable use partially supported	Fecal Coliform (violations in 2 out of 12 samples in 2002)
Rivanna River	The 13 Miles downstream from the confluence of the North and South Rivanna Rivers to the confluence with Buck Island Creek.	Aquatic life use partially supported	Benthic community (appeared impaired in 1998)

Biological Monitoring / Biological Integrity

Biomonitoring involves the sampling of aquatic organisms, usually aquatic insects, in an effort to assess stream conditions. The character of the aquatic community is an indicator of the character of the stream. It is a tool that may have connections to source water protection, particularly in the context of citizen monitoring. Biomonitoring should not be oversold, however. Aquatic insects are often more indicative of habitat conditions than the water quality conditions that are the primary concern with drinking water. Also, biomonitoring is a fairly coarse measuring tool compared to chemical monitoring.

There are at least three qualities of biomonitoring that offer connections to source water protection. First, biomonitoring that involves volunteers has a great deal of educational potential for the public. Second, biomonitoring highlights connections between drinking water protection and other water protection efforts that interest people such as fishery protection or general ecological protection. Third, biomonitoring is a general surveillance technique. Because the organisms are in the stream all the time, they integrate the conditions over long periods of time. Chemical monitoring, by contrast, provides a snapshot at the moment the sample is taken. Biomonitoring is more likely to pick up an occurrence between sampling events. It also helps to track general watershed impacts from development and other land uses.

The leading volunteer monitoring program in Virginia is a program of the Izaac Walton League called Virginia Save Our Streams (VA SOS). Biomonitoring has been done using the VA SOS methods in the South Fork Rivanna Reservoir Watershed and much of the Rivanna River Watershed by the Rivanna Basin Roundtable, Environmental Education Center, Rivanna Conservation Society, Friends of the Moormans, StreamWatch, and others (Figure 39). The same method may be used in the County's stormwater master planning process. Whether or not biomonitoring is deemed an appropriate tool for source water protection by the County or RWSA, it will be important to look for opportunities to support, encourage, and interact with volunteer efforts in the community.

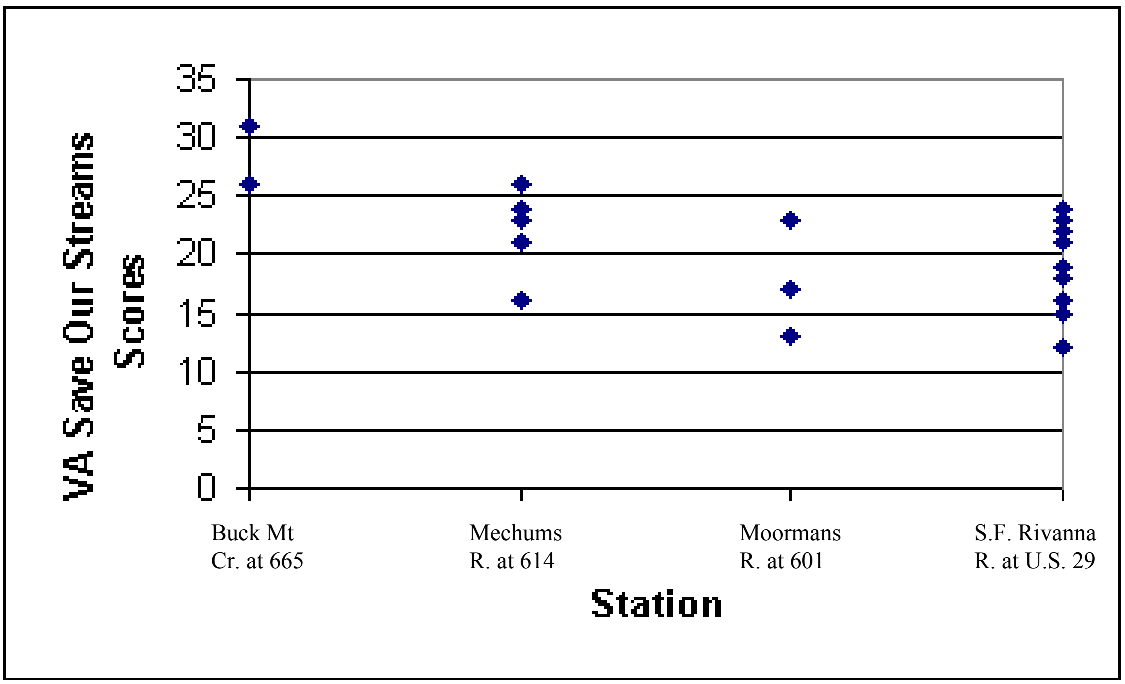

Figure 39. Scores from Virginia Save Our Streams volunteer monitoring of tributaries and the tailwater of the South Fork Rivanna Reservoir near Charlottesville, VA (Virginia Save Our Streams 2001).

Moving Forward

If, as recommended, the watershed management plan is to be updated, several approaches could be taken. In one approach, individual elements of an update could be developed separately to address specific topics. For example, a stand-alone stream buffer restoration plan could be developed. General land use planning might be addressed in separate step. Each topic area would be addressed by the most important partners and stakeholders. Alternatively, a single updated version of the watershed plan could be developed.

The development of the 1979 plan would be one model for the single plan approach. The 1970's Watershed Management Plan Committee comprised the following experts and interests:

- Technical Expertise:
  - Rivanna Water and Sewer Authority
  - Soil Conservation District (now Thomas Jefferson Soil and Water Conservation District)
  - Virginia Department of Health
  - Virginia Division of Forestry (now Department of Forestry)
  - Virginia Water Control Board (now represented by Department of Environmental Quality staff)
  - Virginia Department of Highways and Transportation (now Department of Transportion)
  - Extension Service of Virginia (associated with Virginia Tech)
  - Soil Conservation Service (now Natural Resource Conservation Service, USDA)
  - Agricultural Stabilization and Conservation Service, (now Farm Services Agency, USDA)
  - United States Environmental Protection Agency (Ex Officio)
- Stakeholder Interests:
  - Charlottesville City Council Member for Consumers
  - Citizen of Albemarle County – Earlysville
  - Citizen of Albemarle County – Ivy
  - Citizen of Albemarle County – Crozet
  - University of Virginia Water Consumer
  - University of Virginia Citizen at Large
  - Citizen from the Agricultural Industry
  - Citizen from the Forestry Industry
- Staff/Albemarle County:
  - Consultant
  - County Executive
  - County Engineer
  - Environmental Scientist

Funding for the project came from the State Water Control Board and the USEPA (F.X. Browne Associates, Inc. and the Watershed Management Plan Committee 1979). From the documentation, it appears that the bulk of the scientific work was carried out by the consultant, F.X. Browne and Associates, Inc. The committee received the scientific information and laid out recommendations. Most of the recommendations required implementation by Albemarle County, the RWSA, or local representatives of state and federal agencies. The committee had little if any implementation or enforcement power itself.

A significant change since the 1970s is the increase in staff assigned to work on water resource protection. Albemarle County has three staff positions assigned entirely to water resource protection (in contrast to none in the 1970s) and several other staff members with responsibilities that relate to protecting water. The RWSA, City of

Charlottesville Public Works Department, and Thomas Jefferson Soil and Water Conservation District have more staff with water related expertise than in the 1970s. RWSA remains the water wholesaler in the community and there will be a role for the Albemarle County Service Authority (ACSA) and the City of Charlottesville.

Representation on a committee would need adjustment to address current situation. For instance there is more water related citizen advocacy than in the 1970s which might suggest new stakeholder representation. Also, the development of the Chesapeake Bay protection effort (started at the federal level in 1983) might mean that new experts are needed to assure synergy with regional efforts. Similarly, experts might be needed to represent the variety of open space and conservation easement programs that exist today.

The RWSA Board is the logical place to start the discussion about updating the plan. The RWSA Board is also the logical body to layout and oversee a plan update process. However, it would also be important to achieve acceptance of the plan process from the Albemarle County Board of Supervisors, Charlottesville City Council, and Albemarle County Service Authority Board of Directors, all of whom could be affected greatly by the plan outcome.

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SOUTH FORK RIVANNA RESERVOIR AND WATERSHED: REFLECTING ON 36 YEARS, ANTICIPATING 50 YEARS

APPENDIX I: THE 1979 SOUTH RIVANNA WATERSHED MANAGEMENT PLAN AND A DISCUSSION OF UPDATING THE PLAN

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Watershed Manager

Prepared for
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Spring 2003

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1979 WATERSHED MANAGEMENT PLAN

The 1979 Watershed Management Plan is included in this appendix. In each section, comments in *italics* provide updated information. (These notes were not part of the original plan). Several elements of watershed management not anticipated in the plan have arisen in the 23 intervening years. One of the most important is the development of a stream buffer protection ordinance that was not yet enabled under state law in 1979. This ordinance protects buffers mainly on new residential and commercial development. Another change has been the acquisition of the Buck Mountain Creek land in the middle 1980s. The Watershed Manager assists with the management of that land (and other RWSA managed land) which totals 0.8% of the SFRR watershed. Water quality monitoring was a major unanticipated task for previous Watershed Managers and promises to be again. In the summer of 2003, the Watershed Manager position is being moved from the Albemarle County government to the Rivanna Water and Sewer Authority but watershed management will continue to be a joint effort.

SOUTH RIVANNA RESERVOIR

WATERSHED MANAGEMENT PLAN

VOLUME 1 – EXECUTIVE SUMMARY

PREPARED BY

F.X. BROWNE AND ASSOCIATES

AND

WATERSHED MANAGEMENT PLANN COMMITTEE

FOR

COUNTY OF ALBEMARLE
CHARLOTTESVILLE, VIRGINIA

AUGUST 1979

WATERSHED MANAGEMENT PLAN COMMITTEE

Edgar N. Garnett – Chairman, Citizen Representative of Agricultural Industry
J. Gordon Yager – Vice-Chairman, Soil Conservation Service
Dr. Rolf Benzinger – Univ. of Va. Representative of Water Consumers
Donald R. Bowman – VPI-SU Extension Service Representative
John M. Carroll – State Division of Forestry
R. E. Conner – Department of Health
Harry L. Garth – Soil Conservation District
Allan B. Kindrick – Albemarle County Citizen (Earleysville)
James E. Maxey – ASCS, Department of Agriculture
C. Tom Mizell, Jr. – State Water Control Board
Nancy K. O'Brien – City Council Representative of Water Consumers
Dr. William E. Odum – Univ. of Va. Citizen at Large
Lily Patterson – Albemarle County Citizen (Crozet)
Walter F. Perkins – Forestry-Industry Representative
Dan S. Roosevelt – Department of Highway and Transportation
Col. Carroll B. Smith – Farm Bureau
Sally Thomas – Albemarle County Citizen (Ivy)
George W. Williams – Rivanna Water & Sewer Authority
Gerald Pollis – U.S. EPA, Ex Officio Member

COUNTY OF ALBEMARLE

Guy Agnor – County Executive
J. Harvey Bailey – County Engineer
Darlene Samsell – Environmental Scientist

RECOMMENDATIONS

4.2 GENERAL AND ADMINISTRATIVE

1. A position of Watershed Management Official should be created to coordinate and review all watershed management activities. The position should be organized in the Office of County Engineer. The duties of the Watershed Management Official should include coordination of all ordinances relating to watershed management including the Erosion and Sedimentation Control Ordinance and the Runoff Control Ordinance. Duties should also include coordination of educational programs, integration of watershed management programs, and coordination and review of best management practice implementation throughout the watershed.
This position was created in 1980 and still exists. The position originally resided in the County Executive's Office. It was later moved to the County Department of Engineering and Public Works. In the summer of 2003 it is being moved to the Rivanna Water and Sewer Authority.

Specific duties of the Watershed Management Official should include, but not be limited to the following:

A. Inspections:
- Soil erosion and sedimentation control work in progress
There are five staff in the County assigned to Erosion and Sediment Control. The Watershed Manager coordinates with them on a regular basis.

- Runoff control work in progress and one year beyond completion
The Watershed Manager helps review stormwater plans and stream buffer protection issues under the Water Protection Ordinance (the current version of the Runoff Control Ordinance). Today, several other staff are involved in WPO review as well. Follow-up on completed structures is carried out by a member of the County Public Works group.

B. Observations:
- Of roads and highways relative to erosion and runoff
- Of subdivisions and developments
- Of rivers and streams
These observations are made informally, and in some instance formally, by Engineering staff as they carry out their work.

C. Education and Information:
- Maintain library of Best Management Practice (BMP) manuals and other pertinent publications
Promoting development-related BMP technology is a function of the Watershed Manager and two other County staff. Agricultural BMP information is a function of the TJSWCD and other agricultural agencies. Both maintain libraries of manuals, etc. The County completed a Design Manual addressing BMPs and much more in February 2003.

- Keep abreast of local, state and federal nonpoint source control programs providing technical and financial assistance

This is a significant task of the Watershed Manager.

- Develop and promote educational programs
- Disseminate watershed management information

Education is a component of the Watershed Manager's workplan. Answering information requests is important as well.

In order to fulfill the inspection duties described above, the Watershed Management Official should act as a deputy for the Zoning Official and for the Runoff Control Official and be provided with the authority their respective officers possess.
Presently the Watershed Manager has authority in the areas of stormwater plan review and stream buffer protection. Other staff have authority in the areas of Erosion and Sediment Control and Zoning.

2. A watershed management education program should be developed. The Watershed Management Official should coordinate this activity.
County Water Resources staff out education projects as opportunities or needs arise. There is no formal education program or plan at present.

3. Implementation of the watershed management program should emphasize the control of both point and nonpoint sources of pollution.
Both point and nonpoint sources have been addressed over the years. Today, the focus is almost exclusively on nonpoint sources.

4.3 RESERVOIR AND WATER SUPPLY

1. The Rivanna Water & Sewer Authority (RWSA) should continue to treat the reservoir with copper sulfate as needed to control algal blooms. In addition to maintaining records of application date, amount and area covered, the RWSA should record the pre- and post-treatment phytoplankton counts and visual observations of the reservoir. Water treatment plant operations should be correlated with reservoir treatment to determine the effect of reservoir treatment on water plant operations.
Copper sulfate (to control algae blooms) was needed fairly frequently into the 1980s. It has been used very rarely since then because of improvements in water quality and water treatment.

2. The Rivanna. Water & Sewer Authority should continue to operate the reservoir aeration system until a full evaluation of its effectiveness is completed. RWSA should maintain records of system pressure and visual pattern to document the general operating characteristics of the system. RWSA should also maintain records of the aeration system's energy usage and operating costs. A benefit/cost analysis of the aeration system should be performed when sufficient environmental and operating data are available.
*Additional study (*F.X. Browne Associates, Inc. 1982*), practical experience, and maintenance difficulties led to an end to reservoir aeration in the late 1980s or early 1990s.*

3. The Rivanna Water & Sewer Authority should continue the use of powdered activated carbon, potassium permanganate or chlorine dioxide at the South Rivanna water treatment plant for the treatment of taste and odor causing substances. RWSA should maintain records of chemical dosage rates, application points and filter backwash frequency. Design of the proposed plant expansion should consider the addition of permanent taste and odor treatment facilities such as granular activated carbon filter media. Flexibility of treatment should be a primary concern in the design of the expanded plant.
Permanent powdered activated carbon and potassium permanganate feed capability were built into the expanded plant and are used when appropriate. The proposal to use of chlorine dioxide is inactive for the foreseeable future.

4. The Rivanna Water & Sewer Authority should initiate detailed studies of the two supplemental water supply alternatives presented in the 1977 Camp Dresser & McKee, Inc., "Report on Alternative Water Supply Sources". The studies should determine the specific land areas to be affected by the alternatives. Special emphasis should be placed on the present and potential location of development in the Buck Mountain watershed and its potential impact on water quality.
Safe yield (for SFRR) in 2000 was down to about 6.5 MGD. A major water supply search project has been underway. The current effort has explored more than 30 alternatives for providing all or part of water supply needs through 2050.

4.4 POINT SOURCES
1. The wastewater discharge of Morton Frozen Foods should be eliminated from the watershed.
See next item.

2. The Board of Supervisors and the Rivanna Water & Sewer Authority should request the State Water Control Board to assign a higher priority to the funding of the Crozet interceptor and set aside grant funds for the interceptor prior to December 31, 1983. The impact of the existing phosphorus discharge of Morton Frozen Foods and the potential impact. of development in the Crozet and Charlottesville urban areas makes the proposed Crozet interceptor an essential element in the watershed management.
The Crozet interceptor went online in 1988. Morton Frozen Foods was purchased by ConAgra. The plant was closed in 2000.

4.5 DEVELOPMENT
1. Existing ordinances relating to control of development and construction activities should be reviewed and revised, if necessary, to conform with the watershed management plan.
There have been multiple ordinance updates. The most recent update (in 1998) created the Water Protection Ordinance (Chapter 17 of the County Code), which through an extensive public process, combined and updated the erosion and sediment control, stormwater, and stream buffer ordinances.

2. Basin-wide stormwater runoff management plans should be developed for the

watershed. These plans would indicate the feasibility of providing regional runoff control facilities such as ponds or grass storage areas for several developments located in the same area. Such regional control facilities might eliminate the need for on-site control facilities and could provide valuable open space for recreational activities.
Basin-wide plans have never been developed. The Lickinghole Stormwater Basin served as a basin-wide measure for the Crozet area. Basins like Lickinghole that impound live streams are now discouraged. Off-line basins are still viable solutions where the administrative and maintenance benefits outweigh the benefits of solely relying on on-site BMPs. The County is currently doing basin-wide planning in the development areas (including Crozet). Sediment forebays on SFRR have been discussed in the Water Supply Project. Otherwise, it may be that these regional solutions are not appropriate outside of the Crozet Designated Development Area.

3. Cluster development, as provided in the Zoning Ordinance, should be encouraged in the watershed. This form of development, if designed properly, minimizes impervious ground cover and maximizes usable open space. This combination reduces the amount and peak flow of runoff from the site and allows for filtration and treatment of runoff by natural site vegetation.
This recommendation anticipated the recommendations of the County's Development Area Steering Committee and the concept of Rural Preservation Developments.

4. Developers should be encouraged to use "natural" engineering techniques in the selection and design of best management practices for development. Innovative stormwater management practices such as use of natural drainage, on-site retention, and land treatment should be encouraged.
Since 1979 this philosophy of site and BMP design has continued to develop. Prince Georges County, MD is a national leader in the field of "Low-Impact Development" and Albemarle County is a regional leader in applying some of the techniques. Still, there is a more progress to be made toward adoption of this design philosophy.

4.6 ROADWAYS

1. In light of the specific eutrophication problem of the Rivanna Reservoir, its use as a water supply, and the potential contribution of sediments and nutrients from construction. activities in the watershed, the Virginia Highway and Transportation Department should be requested to prepare or have their contractors prepare a written erosion and runoff control plan for all construction activities in the watershed. The runoff control plan should be submitted to the Watershed Management Official for review. The Watershed Management Official should perform site visits to highway construction sites to insure that the plan is being implemented and all controls are being properly maintained.
The Virginia Department of Transportation (VDOT) is now required by the Virginia Stormwater Management Act and regulations and the Virginia Erosion and Sediment Control Act and regulations. VDOT employees have been trained to self-inspect the jobs. Local staff does not review VDOT E&S plans. Local staff has no enforcement authority over state projects.

2. The Virginia Highway and Transportation Department should install and maintain erosion and sedimentation control measures as specified in its Erosion and Sedimentation

Control Manual.

3. The Virginia Highway and Transportation Department should encourage the use of innovative erosion and sedimentation control measures for construction activities in the watershed.

4. The Virginia Highway and Transportation Department should include specific provisions for the implementation of erosion and sedimentation control measures in all construction contracts. These provisions should be strictly enforced.

5. The Virginia Highway and Transportation Department, in cooperation with the Board of Supervisors, should initiate a program to correct the severe and moderate erosion and runoff problems observed at various stream crossings. Corrective measures should include implementation of erosion control measures and diversion of roadway drainage through vegetated buffer areas where applicable.

6. The Virginia Highway and Transportation Department, in cooperation with the Board of Supervisors, should initiate a program to correct the erosion problems at steep highway cuts identified in Volume II of the Watershed Management Plan.

7. Roadway and drainage ditch maintenance practices should be studied to determine whether existing maintenance practices can be modified to reduce erosion and runoff problems. The study should be performed by a task committee made up of representatives from the Highway Department, Albemarle County and the Soil Conservation Service.

4.7 STREAMBANK EROSION

1. The Thomas Jefferson Soil and Water Conservation District should develop and implement a streambank erosion control program for the watershed.
Both the TJSWCD and the County have participated in streambank restoration/stabilization as opportunities have arisen. Large-scale streambank restoration is prohibitively expensive. Streambank erosion prevention is a major focus of agricultural cost-share programs.

2. The impact of various land use activities on streambank erosion should be included in the education program developed for the watershed.
Both the TJSWCD and the County have educated the public on streambank erosion with the TJSWCD focusing on farmers and the County focusing on homeowners.

4.8 AGRICULTURE

1. The Board of Supervisors should send a letter to all agricultural producers owning land or operating within the watershed pointing out the importance of protecting water quality from agricultural pollutants and listing those agencies which provide assistance to plan and implement conservation practices.

2. The Thomas Jefferson Soil and Water Conservation District, in conjunction with the ASCS, SOS and other agricultural groups, should conduct an annual Conservation Field

Day to show land users the importance and benefits of sound land treatment practices.

3. The Board of Supervisors should assist the Soil and Water Conservation District, ASCS and SCS in obtaining funds from the ASCS special projects program to promote conservation practices.

4. The Board of' Supervisors should place a requirement on recipients of land use tax benefits to develop a sound conservation plan and seek assistance of local, state and federal agencies to develop such a plan.

5. The Thomas Jefferson Soil and Water Conservation District, with assistance from other agricultural agencies, should actively identify agricultural problem areas in the watershed and volunteer assistance to these farmers. Farm activities in the watershed should also be reviewed to determine fertilizer, pesticide and herbicide application rates and practices.
All farmers in the SFRR growing row crops now have nutrient management plans. There is still a need to identify problem areas - particularly of soil erosion - and seek solutions.

6. Specific watershed management goals should be integrated into agricultural technical and financial assistance programs to emphasize and give priority to problem areas and conservation measures identified in the watershed management plan.
The general goals of the agricultural cost-share programs are the same as those of local water supply protection efforts. However, there is always a need to make a special effort to involve farmers in the SFRR. The complicated paperwork involved in the programs has been cited as a barrier that needs to be overcome.

4.9 FORESTRY
1. Forestry personnel should implement the best management practices described in the Virginia Forestry Manual developed under the Statewide 208 Program.
Virginia Department of Forestry personnel now enforce best management practice requirements on forestry operations. Their efforts are focused on the bad actors.

SUMMARY OF A PUBLIC MEETING ON THE HISTORY AND FUTURE MANAGEMENT OF THE SOUTH FORK RIVANNA RESERVOIR AND WATERSHED

On 4 September 2002 a public meeting was hosted by the RWSA and Albemarle County to discuss the findings of the report, "South Fork Rivanna Reservoir and Watershed: Reflecting on 36 Years, Anticipating 50 Years," and the concept of updating the 1979 plan. A meeting summary follows.

COUNTY OF ALBEMARLE

DEPARTMENT OF ENGINEERING & PUBLIC WORKS

MEMORANDUM

TO: **Lawrence C. Tropea, Jr., Executive Director or the Rivanna Water and Sewer Authority**

FROM: **Stephen Bowler, Watershed Manager**

DATE: **20 September 2002**

SUBJECT: **Summary of the "Public Discussion of a Report on the History and Future Management of the South Fork Rivanna Reservoir and Watershed"**

On 4 September 2002, the Rivanna Water and Sewer Authority and County of Albemarle hosted a meeting at the County Office Building to gather public input to the South Fork Rivanna Reservoir (SFRR) history report and the possibility of updating the 1979 South Rivanna Watershed Management Plan. The meeting was promoted largely via the Internet, particularly through distribution via various organizations' email lists. Forty-five people attended the meeting. Individuals who identified with environmental interests dominated the group. Several people were riparian landowners on the reservoir or its tributaries. People also came from outside the SFRR Watershed including the City of Charlottesville and Fluvanna County. There were two representatives of farming interests, one person from the real estate community, and two County Supervisors. Discussion was energetic, largely freeform, and very polite. Four participants submitted written comments.

A few general themes stood out from the discussion. Much discussion revolved around the point that protection of the SFRR and Watershed should be a "priority in all community efforts," where watershed and landscape planning are integrated and should be incorporated into all decisions made by the City and County. Some speakers emphasized that the County's Rural Area Plan, which addresses future land use, as well as other planning efforts (transportation, biodiversity, greenways, mountain protection, etc.) are critical to SFRR protection.

The point came up multiple times that it is essential to develop a better understanding of the sources of sediment in order to have the cost and benefit information needed to develop and target sedimentation reduction strategies. Impervious surfaces and the preservation/restoration of stream buffers (with native vegetation) were identified as key issues. Participants provided anecdotal evidence of the key role of the deforestation and erosion of stream banks in sedimentation.

The role of growth and urbanization as contributing factors to water supply needs and water quality and quantity impacts was emphasized. Some attendees were concerned that there was not a plan to manage water demand both on an individual and watershed-wide basis. Limiting new growth within the western “sponge” area was suggested as well as requiring development to follow certain specifications inhibiting runoff, such as porous pavement and similar technology.

Finally, several people felt that connections to the larger Rivanna watershed (including Fluvanna County) and to groundwater could not be ignored. In this context the concepts of integrated resource planning, total watershed management, a watershed water budget, a Water Impact Committee much like the County’s Fiscal Impact Committee, and a high-level Rivanna Watershed Commission were put forth. Connections to Chesapeake Bay and Shenandoah National Park also were mentioned as important.

Attendees were asked for specific information that would help in considering the prospect of a plan update. Suggestions for possible members of a body that could be charged to develop a plan included the Thomas Jefferson Soil and Water Conservation District, the Dept. of Game & Inland Fisheries, the Rivanna Conservation Society, farmers, technical people, citizens, County planning staff, the City of Charlottesville, and Fluvanna County. Speakers mentioned that a plan would benefit from an integrated mission statement, an implementation plan (with dates and specific goals), lessons from the previous plan, and an education component. It was pointed out that the Water Supply Project needed to move forward. Related efforts, such as sedimentation research or a watershed management plan update, could occur in a parallel and supporting role to the Water Supply Project.